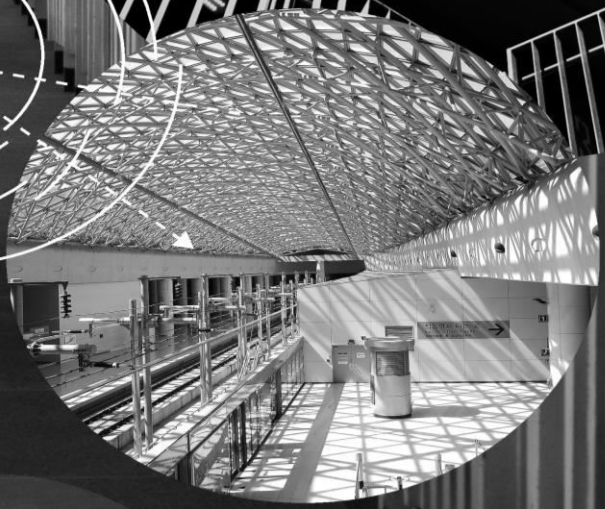
BUILDING AND SPACES



AR. PREETI NAIR | DR. PRANAY TANWAR
DR. MOHD ATIF WAHID | AR. SWATI PUNYAL

Building and Spaces

EMPYREAL
PUBLISHING HOUSE

India | UAE | Nigeria | Uzbekistan | Montenegro | Iraq | Egypt | Thailand | Uganda | Philippines | Indonesia

www.empyrealpublishinghouse.com

Building and Spaces

Edited By:

Ar. Preeti Nair
Department of Architecture, Delhi Technical Campus, Greater Noida

Prof. Pranay Tanwar
Dean Academics, Delhi Technical Campus, Greater Noida, India

Dr. Mohd Atif Wahid
Department of Mechanical and Automation Engineering at Delhi Technical Campus, Greater Noida, India

Ar. Swati Punyal
Department of Architecture, Delhi Technical Campus, Greater Noida

First Impression: May 2023

Building and Spaces

ISBN: 978-93-93810-64-9

Rs. 1000/- ($80)

No part of the book may be printed, copied, stored, retrieved, duplicated and reproduced in any form without the written permission of the editor/publisher.

DISCLAIMER

Information contained in this book has been published by Empyreal Publishing House and has been obtained by the editors from sources believed to be reliable and correct to the best of their knowledge. The authors are solely responsible for the contents of the articles compiled in this book. Responsibility of authenticity of the work or the concepts/views presented by the authors through this book shall lie with the authors and the publisher and editors have no role or claim or any responsibility in this regard. Errors, if any, are purely unintentional and readers are requested to communicate such error to the author to avoid discrepancies in future.

Published by:
Empyreal Publishing House

ACKNOWLEDGEMENT

The Editors would like to thank everyone who contributed to this book, especially the authors and review team members. This book would not have been possible without their help.

First and foremost, the Editors would like to thank all authors for their efforts. We sincerely thank the chapter authors for donating their time and skills to this publication. They gave their knowledge and helpful input in the goal of ensuring the manuscript is of the highest possible quality.

Second, the Editors would like to thank the reviewers for their substantial contributions to the improvement of chapter quality, coherence, and content presentation. Some authors also served as referees; we highly appreciate their double task.

The vision of publishing book could not have been realized without the unwavering support of management and higher officials at the institute level. Their patience and advice made this task possible.

Special thanks go to the book's Editorial and Empyreal Publishing House (EPH) team for their vision in organizing this volume and diligence in compiling the entire book in a professional manner.

Ar. Preeti Nair
Prof. Pranay Tanwar
Dr. Mohd Atif Wahid
Ar. Swati Punyal

Table of Contents

Chapter 1

TINY LIVING: MAXIMIZING SMALL SPACE USAGE IN MICRO APARTMENTS

Amitesh Vijay Mourya[1*] and Khushboo Agarwal[2]
[1]Associate Professor, Delhi Technical Campus, Greater Noida, India
[2]Student, Delhi Technical Campus, Greater Noida, India

ABSTRACT
There was a time when "compact living" was a huge utopian fantasy. Today, with all of its truth, this dream is emerging from the ashes. Micro flats, compact units, nano capsules, small houses, and a slew of other terms began to appear in densely populated areas such as New York City, Japan, Hong Kong, Delhi, and now in Mumbai, to mention a few. These units are a spatial depiction of the philosophy of "RIGHT sizing" rather than "downsizing." It essentially advises maximizing space efficiency by resizing personal spaces, introducing multi-functional, transitional spaces, and so on. The new way of life is to live small. Designers and developers have turned their focus to tiny living as the tiny house movement has grown in popularity and urbanization has spread. As a result, a swift transformation from unreasonably tight spaces into well-planned micro flats has occurred, addressing to the requirement for living space in megacities with limited space. These micro apartments have become increasingly relevant in the last few decades as an upcoming trend for residence in urban cities. In this context, the purpose of this article is to explore the demand for micro residences in utilization.

Keywords: Compact Living, Optimizing, Utilization, Micro apartments, Maximizing small space usage, Layout, Adaptive furniture

1. INTRODUCTION
Although there is no universal definition of a micro apartment, a workable definition is a small apartment of less than 400 square feet with a fully functional and accessible kitchen and bathroom. A 160-square-foot single-room-occupancy (SRO) unit that uses common kitchen or toilet facilities does not qualify as a real micro apartment under these criteria [1].

Micro-apartments (also known as micro-units) are studios that are smaller than ordinary, ranging in size from 200 to 400 square feet. Even smaller, up to 150 square feet, is possible. Micro-units are not one-bedroom apartments [2]. They're frequently an open concept space that combines a bedroom, living room, and kitchen. A micro-apartment may also be described as a compact efficiency flat with few facilities and a lofted bed to save space.

Expanding urbanization and scarce of land availability in desired locations have urged to need for the designers, planners and architects to adapt concept of micro apartments as the next best housing solution.

The surge in housing demand and changing lifestyle has evolved design of housing typologies to result in the addition of micro apartments in the category. Micro flats are defined by their ability to maximize limited spaces while maintaining high quality of life. The research on maximizing small spaces usage in micro apartments tends to define the possible extend to which the design may be used to its full potential [3].

This study is to bridge a gap in understanding the different possibilities of maximizing small space usage in micro apartments which could help evolve the concept of “not downsizing” by “right sizing” for housing design in near future.

2. BACKGROUND

2.1 Conventional Studio Apartment V/S Micro Apartments

The main arrangement of a micro apartment is similar to that of a studio, and it contains a kitchen with full-size appliances. The size difference between a micro apartment and a studio is the size. A micro apartment is usually 100-400 square feet in size [2].

In a 300-square-foot micro apartment, the kitchen will take up around 60 square feet, while the bathroom will take up about 30 square feet. Only 210 square feet of living space remains, approximately the size of a one-car garage (minus the closet, if there is one). [4] The fig 1.1below shows difference b/w conventional vs micro apartments.

Figure 1.1 Conventional v/s micro apartments
(***Source:*** ISSUU https://issuu.com/source_magazine)

2.2 Tiny House Movement & Evolution of Micro Apartments

The tiny-house movement (also known as the small-house movement) is an architectural and social movement that promotes downsizing, simplification, and "living with less." A tiny home is defined as a "dwelling unit with a maximum of 37 square meters (400 sq ft) of floor space, excluding lofts," according to the 2018 International Residential Code, Appendix Q Tiny Houses.

In the last decade, the micro-living craze has exploded. This living situation is not a novel concept that seeks to leave the smallest possible footprint on the world. If one tries to trace the origins of micro-living, it is possible to link it to early stone age shelters, American native tepee tents, eskimos' igloos, and austere monk cells in the context of providing just fundamental human requirements [5]. However, in order to better comprehend how the concept of micro-dwelling is growing in cities today, it may be more useful to concentrate on the twentieth century and later, which may be considered the start of small-scale living.

Figure 1.2 Left: Love2 House by Takeshi Hosaka Architects
(***Source:*** Fujoo Nacasa & Partners Inc);

Right: Studio Flat by Hiroyuki Ogawa Architects (Source: Dezeen https://www.dezeen.com/)

2.2.1 Various parameters that result in need to adapt micro apartments over traditional studio apartments are listed as below:

a) Relative minimum space requirements

b) Housing as a global crisis

c) Shifting demographics and rising interest in single living

d) New generation and new habits

e) Times of uncertainty

2.3 Target Occupants

Micro-apartments can accommodate people of all ages and demographics. They are, however, aimed at single twenty-somethings and millennials who work in cities. Their income levels are frequently greater than the average. People in that age group are also interested in everything that city life has to offer, from bars and restaurants to museums and parks **[6]**.

Micro-living is all about convenience and elegance. As a result, they have become the greatest option for the younger generation (adults under 35 years old), professional singles, and millennials who want to live in excellent megacity areas at their leisure.

2.4 Pros and Cons of Micro Apartments:

2.5.1 Pros of Living in a Micro Apartments

a) Rent/purchase cost savings

b) Less furniture means more money in your pocket.

c) Live in the most desirable locations

d) Get rid of your car and other services

e) Contribute to the environment

2.5.2 Cons of Living in a Micro Apartments

a) The location is pricey

b) A scarcity of space

c) Having guests over is difficult

d) Lack of adaptability

2.5 Maximizing Small Space Usage

The small spaces can be utilized efficiently and perceived larger with changes in the layout, living style and design of the unit. All the aspects are discussed in the following sub headings:

2.5.1 Layout & Space Design Elements (Fig 1.3)

a) Zoned open-plan space layout

b) Use folding glass walls to achieve dynamic and flexible space separation

c) Addition of mezzanine floor

d) Sliding staircase – movable elements which, if necessary, can be hidden or blend

e) Multi use of same space – foldable bed

f) Movable wall in combination with folding wall/murphy bed

Figure 1.3 Layout & design layout
(***Source:*** Interiorzine https://www.interiorzine.com/)

2.5.2 Furniture & Storage (Fig 1.4)

a) Door used as book self – multi use furniture

b) Make the most of high ceilings

c) Creating a special unit for sleeping and using its volume for storage compartments

d) Saving Space with a Suspended Bedroom

e) Elevating the kitchen and hiding the bed underneath

f) Turn the bedroom it into a sculptural element

g) Furniture Island in the middle of the living space

h) Hide the desk when is not in use

i) Sliding bed under the working place

j) Multi use movable table concealed in the closets

k) Flat-pack furniture of the future

l) Introduction of movable furniture

Figure 1.4 Furniture & storage (***Source:*** Interiorzine https://www.interiorzine.com/)

2.5.3 Lighting and Color

a) The mix of white and wood as a color scheme is usually a winner.

b) Use dark hues if you want to appear bold.

c) Some of the furniture is painted in bright colors.

d) Allow light to shine.

2.5.4 Materials and Finishes

a) Use your imagination when it comes to materials.

b) Using reflective surfaces to create the appearance of volume

c) The floor and ceiling cladding have contrasting textures.

d) Metal structure with excellent transparency

3 EXAMPLES OF MICRO APARTMENTS

3.1 CASE I: CARMEL PLACE, MANHATTAN

Location: 335 E 27th Street, Kips Bay, Manhattan, NY

Architect: nArchitects

Status: Completed

Years: 2013-2016

Sq Footage: 35,000sf

Program: Manhattan's first micro unit apartment building, with 55 micro-unit apartments, shared amenities, and retail.

Environmental: LEED Silver target

3.2 CASE II: THE AVENIR, PHILIDELPIA

Location: 15th and Chestnut Streets, Philadelphia, Pennsylvania

Architect: Floss barber, an interior firm

Status: Completed

Years: 2015

Sq Footage: 149000 sf

Program: Half regular/half micro unit apartment complex

3.3 CASE III: THE PANORAMIC, SAN FRANCISCO

Location: soma, mission street, san francisco, CA, USA

Architect: kwan henmi architecture and planning

Status: completed years: 2015

Sq footage: 108,000 +/- sf

Program: 1 story furniture store transformed to 11-storey micro-apartment

4. JUSTIFICATION OF HYPOTHESIS

Amidst the process of understanding the concept and need of micro apartments, the case study analysis clearly helps in justifying that through careful planning and adopting the concept of "right sizing" instead of "downsizing" and bringing the space utilization to its maximum the micro apartments can be introduced as a new housing typology for the fast-growing cities.

4.1 Future Scope

Being a new concept "micro apartment", the scope on further study of this topic is vast. The future scope of this research can be focused on defining further constraints and identifying parameters (like introducing them with modular/fast-pace construction) for designing layouts through generative design by merging humans, space and technology [7]. Also, future study on conceptualizing similar framework by identifying parameters could be generated for introducing micro apartments as type for affordable housing, students housing (like in one of the projects), or in mixed use projects [8].

4.2 Recommendations

Through literature study we could establish that micro apartments being a new concept lack in standard specifications and other guidelines that can be studied or referred to while designing micro apartments that would help in maintaining balance between small space planning and living comfort of the occupants. Hence, in future few standards could be introduced specific to small space design to act as guides for designing of micro apartments.

5 CONCLUSIONS

In the midst of changing lifestyle dynamics and need fleeting urbanization introduction of micro apartments as micro apartments and "right sizing" of the same has become an appealing approach towards housing design. This research, establishes the factors that have resulted in the evolution and implementation of micro apartments as a new typology in modern housing construction.

Amongst the wide range of abstract as well as physical aspects, that governs the maximum space usage, in this research spatial planning is studies through aspects of layout planning, adapting modern adaptive furniture by the analysis of three projects varying in parameters like design style, construction techniques, target users and layouts variety.

The key findings from the case studies of few of the best designed micro apartments in the world and their comparative analysis validates those solutions like multi-use spaces, modular and adaptive furniture and introducing common amenities in apartments can be certain constant parameters in maximizing space usage in micro apartments.

REFERENCES

1. Z. Z. V. P. Al-yakoob Dania, "Micro-Apartment In Pontianak," JMARS: Jurnal Mosaik Arsitektur, pp. 258-269, 2021.
2. L. Wen, "Research on Small Apartments Design," Frontiers in Educational Research, pp. 32-35, 2018.

3. I. J. o. E. R. &. Technology, "Optimizing The Spatial Configuration of Existing Micro-Apartment Designs in Developed Countries," pp. 24-47, 2022.
4. D. Fisher-Gewirtzman, "The impact of alternative interior configurations on the perceived density of micro apartments," Journal of Architectural and Planning Research, pp. 1-12, 2017.
5. M. S. S. Honig, "The sacrifice of space: transgressive tactics for micro-apartments," Spring 5, 2016.
6. A. W. Woro Medha Mahardhika, "Liveability indicators of micro-apartment interiors in Jakarta and Bandung," Serat Rupa Journal of Design, 2023.
7. L. Bhandari, "Micro Study on Housing in India," Indicus, pp. 1-82, 2003.
8. I. M. Rian, "Multicultural Flexible Housing: Addressing the Need and Scope of Flexible Housing in Cosmopolitan Indian Cities," Built Environment in Developing Countries, pp. 1-21, 2011.

Chapter 2

APPLICATION OF BIOMIMICRY IN BUILDING DESIGN

Seema Sharma[1*] and Pankaj Prabhakar[2]
[1]Associate Professor, Delhi Technical Campus, Greater Noida, India
[2]Student, Delhi Technical Campus, Greater Noida, India

ABSTRACT
The main structure of the research is the investigation of the application of biomimicry on the building envelope and its reaction to architectural design issue. It looks at nature as a possible solution to these problems. Its discussion of alternative tactics for generating an architectural configuration consistent with its structure continues. Incorporating biomimicry concepts into architectural design is expected to be more sustainable and efficient in terms of future energy usage and operational cost consumption reductions, as well as design renewal. The focus of this research is to explore how the idea of inspiration from nature can be used to overcome adversity through design methods. The paper concludes with the formulation of a design guideline based on clear biomimetic theories which could be implemented to any building design in consideration to contexts, to achieve efficiency in design of the building.

Keywords: Biomimicry, Mimicking Nature, Building Design.

1. INTRODUCTION
The words "biomimicry" and "mimesis" are Greek words that mean "life" and "imitate," respectively (imitation). Biomimicry is an innovation strategy that tries to develop long-term solutions to human issues by replicating natures tried-and-true patterns and strategies. The goals to create long-term solutions, processes, regulations, and new belief systems that are compatible with life on Earth [1].

The idea of biomimicry is to adapt ideas learned from natural selection to human engineering. The biomimicry approach favors “options” that have been tried and tested by evolution over billions of years to determine what works and what does not. In the long run, biometric-based designs will enable human production to become more efficient, resilient, and sustainable [2].

A Few Thoughts on Biomimicry –
The underlying point is that nature has already provided solutions to many of the issues that society faces. Microorganisms, plants, and animals all have extensive engineering backgrounds [3]. They are aware of what functions, what is proper, and—most importantly—what endures on Earth. The biomimicry approach is based on the concept that what didn't work after 3.85 billion years of development is now a fossil, and what's around us is the key to survival.

The aim of the research is to develop a link between biomimicry and building design, i.e., biology and architecture, and to determine the best way to design utilizing biomimicry principles. The objectives are summarized below:

- To understand the concepts of biomimicry and examine its use in architecture.
- To study the need of biomimicry in building design.
- To understand the varied applications of biomimicry in building design.
- To explore potential applications of biomimicry.

2. WHY BIOMIMICRY?
Why is it necessary to take a biomimetic approach to building design? Undoubtedly, it is one of the best sources of solutions that will allow us to create a better future and move humanity from the industrial to the ecological period [4].

It doesn't have to mean exactly replicating the natural form or process, but rather using it as a steppingstone for new ideas based on its lessons. It is the key to all man-made problems that one is currently facing, as well as any obstacles that may arise in the future [5].

2.1 Research Questions

- How can planning and design draw inspiration from biomimicry and the biological world?
- Why do we need to study biomimicry and how con it helps attain more environmentally conscious and creative buildings?
- How does biomimicry inspire creative innovation in building design?
- What is biomimicry's potential as a design method?

2.2 Scope

The scope of this study encompasses following:

- To understand the existing philosophy behind Biomimicry.
- To focus upon Biomimicry's application in design and planning.
- To do a comprehensive analysis of Biomimicry as a concept and its efficiency in present context.

2.3 Hypothesis

Biomimicry as a design concept has the potential to become the mainstream design concept with respect to its present off-beat status.

3. Literature Study

This literature study aimed at understanding biomimicry and how the principles of nature can be implemented in the field of architecture.

Biomimicry is defined as the science of using nature's models, systems, processes, and elements to address design issues in a sustainable manner. To consciously emulate nature's genius, we must see it in a better perspective [6].

Based on natural events, biomimicry is a type of creation. In her book Inspired by Nature, Janine Benyus outlines nine fundamental principles that guide the practice of biomimicry. As a result of the biomimicry principles' exclusive focus on natural qualities, humans may be able to learn a lot from the evolution of the natural world over billions of years [7].

They are as follows:

- Nature moves on daylight
- Nature utilizes just the energy it needs
- Nature combines form and function
- Nature recycles everything
- Nature encourages cooperation
- Nature capitalizes on diversity
- Nature calls for local expertise
- Nature seeks balance
- Nature harnesses the power of limits.

3.1Approaches to Biomimicry

The Design phase of biomimicry is typically divided into two classes: defining characteristics, behavior, or function in an entity or ecosystems and interpreting that into human design (design referring to biology) and describing a human need or issues to be addressed and trying to find solutions in other organism or ecosystems (design referring to biology) (biology influencing design) [8].

3.1.1 Problem-Based Approach

The approach of finding out solutions in the human world needs architects describing challenges and researchers linking these with organisms that have resolved similar issues. Architects who recognize initial design goals effectively lead this approach. Carl Hastrich proposed that they depict the process in a spiral so that designers can understand it visually.

3.1.2 Approach Based on Solution

The design collaboration method is primarily based on individuals understanding about suitable biological or ecological studies instead of definite human design concerns when biological information impacts human design.

As a result of this technique, biology may have an unexpected impact on individuals that is unrelated to a preconceived design challenge, leading to earlier unimagined technologies, schemes, or even design solutions. True changes in how humans design and what is prioritized as a solution to a problem are feasible with a biomimetic design approach.

3.2 Levels of Biomimicry

Pederson Zari offers an alternative approach. He devised a typological approach after realizing the benefits of dividing biomimicry into three stages. Organism, behavior, and ecosystem are the three layers recognized.

1. Organism Level

Grimshaw's architecture for The Waterloo International Terminal was inspired by the flexible structure of creatures with scaled facades, such as pangolins. Variable pressures and shifting forces occur as trains arrive and depart from the station, and the design must cater for these variations by using a 'scaled' external facade.

2. Behavioral Level

Mimicking An Action Taken By Nature.

A behavioral example of biomimicry in architecture is the CH2 Building in Melbourne, Australia. To create a thermally stable interior atmosphere, the design of this structure is partly inspired by passive airflow and heat management techniques found in termite mounds. Similar to how certain ant species use aquifer water, water that has been retrieved (and treated) from the sewers under the CH2 Building is used as an evaporative cooling mechanism.

3. Ecosystem Level

Mimicking a Substance's Functionality or the Functioning of Natural Ecosystems

The benefit of this level of biomimicry design is that it may be merged with other levels of biomimicry design (organism and behaviour). It is also possible to use current non-biomimetic sustainable construction techniques like interfaced or bio-assisted structures, which merge human and non-human structures for mutual benefit. The Lloyd Crossing Project in Portland, Oregon, was proposed by a designer team that includes Mithfin Architects and GreenWorks Landscape Architecture Consultants, and it serves as a good example.

The project uses Predevelopment Metrics TM to define targets for the project's ecological performance over time. These are estimates of how the ecosystem that existed on the site before to development functioned.

Each level is further broken down into five possible means of mimicry:

1. **Form:** shape
2. **Material:** properties
3. **Construction:** arrangement or composition
4. **Process:** mechanism
5. **Function:** application

4. CASE STUDIES

4.1 THE EDEN PROJECT, ENGLAND

Table 2.1 Brief Summary of the Building

Location	**St. Blazey, Cornwall, England**
Architect	Sir Nicholas Grimshaw
Building Type	Biome
Client	The Eden Project Ltd.
Project Area	23,000 m^2
Date of Construction	1998-2001
Site	The Bodelva Pit

4.1.1 Introduction

The Eden Project, which began as a millennium project for the general public in the UK, has evolved into a tourist attraction as well as a research and education tool for future generations. The goal of the Eden Project has always been to raise understanding and responsible management of the critical interrelationship across plants, people, and resources, culminating in a more sustainable future for all. The brief summary is given in Table 2.1.

4.1.2 Site Details

The first step in obtaining the form was to examine the site. The Bodelva pit, near St Austell in Cornwall, was a China clay pit towards the end of its operational life.

The crater spanned approximately 22 hectare and varies in size depths ranging from 30 to 70 metre.

Site Advantages

- It receives ample of sunlight
- It has a south-facing slope and
- It is relatively accessible

Disadvantages

- The ground material on the site was mostly clay, which lacks the nutrients required for significant plants growth.
- Before the team could start building the greenhouses, they required to create a layer of nutrient-rich soil.

Tim Smit, who worked on and was mainly responsible for the successful restoration of The Lost Gardens of Heligan, came up with the idea for the three biomes. This time, his goal was to construct something entirely new, from the ground up, that would astound future generations. Through the study and education of plants, this structure aims to educate tourists about the importance of a sustainable environment. Tim collaborated with the world-renowned sustainable architecture company Nicholas Grimshaw and Partners to achieve this goal. They

collaborated on numerous innovative approaches for creating the world's largest biome. The Eden Project consists of three biomes: humid–tropics biome, warm temperate biome, and mild temperate biome, which is the area that surrounds the two contained bubble-like constructions.

4.1.3 Inspiration

To achieve its goal of sustainability, the Eden Project employs a range of design concepts:

- The project was to be the largest plant enclosure in the world. This entailed creating a design system that could cover long distances without relying on a single internal support.
- The design must be as lightweight as possible. A lighter structure would reduce soil stress and allowing for fewer footings and less effect on the site.
- The enclosure must be environmentally sustainable in order to be utilized as a teaching tool on sustainability

4.1.4 Structure & Construction

To create a functional spherical shape, the solution to this problem was to seek to nature for inspiration. The honeycomb hive of bees and even the multi-faceted eye of a fly inspired him. These organisms utilized the most use of their surroundings to produce an extremely powerful; nonetheless, it is a lightweight solution. Furthermore, the clayey soil's growing and shrinking contours might be accommodated by a geodesic dome like structure. The Eden structure is made up of 625 hexagons, 16 pentagons, and 190 triangles. This weight (667 tonnes) is distributed evenly throughout the structure, requiring only support around the dome's base, and providing plenty of space for the plants inside.

4.1.5 Materials

The dome's borders are supported by a strong foundation necklace, which is an underground concrete wall that wraps around the structure's perimeter.

The geodesic hexagonal bubbles inflated with air were made of Ethylene Tetrafluoroethylene (ETFE), a lightweight and robust polymer. Air-filled cushions cover the more than 800 hexagon components. These pillows are made of EFTE foil that is translucent. The base material is between 50 mm and 200 mm thick and 1.5 m wide. The foil was sliced and soldered together. Normal cushions are composed of three layers.

The cushion is formed by the top and bottom layers, which carry the weights. An additional layer between them improves temperature insulation while also splitting the airways in the event of leakage.

4.2 LOTUS TEMPLE (NEW DELHI, INDIA)

Table 2.2 Brief Summary of the Building

Location	**New Delhi, India**
Architect	Fariburz Sabha
Building Type	Worship place
Client	National Spiritual Assembly
Project Area	24 Acres/10,5000 m^2
Date of Construction	1978-1986

4.2.1 Introduction

- The Lotus Temple, also known as the Baha'i House of Worship, is not only a marvel of modern Indian architecture, but it is also one of the world's most visited religious sites. The Temple, on a 9.7-hectare site near Nehru Place in South Delhi, is a place of worship for individuals of all colours, beliefs, and castes. The brief summary is given in Table 2.2

- This House of Worship is designed in the shape of a lotus flower, which is regarded by most Indians. It is intended to represent the purity, simplicity, and cleanliness of the Baha'i Faith while also serving as a symbol of humanity's and faiths' harmony.
- The Lotus Temple, according to Bahá' literature, is a nine-sided circular structure with 27 "leaves" (marble-clad free-standing concrete slab) organised in groups of three on each of the temple's nine sides. The structure is influenced by the lotus flower and is one of the most visible examples of biomimicry in modern architecture.
- The aforementioned "leaves" are classified into three types and are vital for the space's organisation:

➢ **Entrance Leaves -** The entrance leaves (there are nine in total) denote the entry on each of the complex's nine sides.

➢ **Outer Leaves -** The outer leaves form the ceiling of the auxiliary spaces.

➢ **Inner Leaves -** The central worship space is defined by the inner leaves. The worship area is completed with a spectacular glass and steel skylight that approaches but does not meet at the peak of the inner leaves.

4.2.2 Site Details

- The location is well-connected to the entire Delhi region or area via various transit systems such as metro lines, city bus services, and highways, among others.
- The approach road to the Lotus Temple is 8 metres wide. The nearest metro station is Kalkaji Metro, which is around a half-kilometer away. It is near Nehru Place and the Kalkaji Temple.
- On a visual axis, the lotus temple is located on the highest point of the site. From the visual axis, the adjacent temples, such as Kalkaji Madir and Iskon Temple, are visible.
- Because the site's main axis slopes up towards the temple, the view of the temple from the primary leading vista is both daunting and majestic.

4.2.3 Inspiration

- When seeing Hindu-Indian architecture, it is clear that despite their exterior distinctions, all temples portray profound and sacred symbolism shared by all faiths in India. These are symbols seen in a wide range of civilizations and religions. One of these emblems is the lotus flower, which is sacred to the Indians.
- Fariborz Sahba named the temple after this flower, which represents cleanliness and hygiene in Hindu culture. This concept had to be translated into geometric elements like cylinders, spheres, toroids, and cones, which were then put into equations and used as the foundation for structural and engineering layout analysis. The resulting geometry was so intricate that it took two years and six months to complete the temple plans.
- The architect travelled around India to study the country's architectural designs and was inspired by temple designs, artwork, and religious themes, all of which contained the lotus flower.
- Inspired by this experience, he designed the Delhi temple in the shape of a lotus flower to depict the Bahá' faith's concept of purity, innocence, and cleanliness.

4.2.4 Structure & Construction

- Due to the intricacies of the structure and the large number of labour required, a flexible management group with a high degree of innovation was required.

- One of the most important techniques to achieving the set goal was to foresee problems and solve them through experiments and modelling.
- The 9 faces were created by forming the building's 27 reinforced concrete components into flower petals, which were then coated in marble and arranged in threes. Certain architectural elements, such as the circular form with 9 sides specified in the Bahá' scriptures, are shared by all Bahá' Houses of Worship.
- The shell surfaces on either side of the entryways and the outer leaves are mostly made up of spheres of varying radii, with their centres distributed throughout the structure.
- There is a group of spheres that delineate the inner layer of the shells and the outside surfaces of the shells for the entering leaves. The sphere diameters have been changed to accommodate for the structural issues of the petals' varied thicknesses.

4.2.5 Materials

- All of the shells have an exposed concrete surface that is uniformly bush hammered, with architectural designs on the interior surface.
- Crossing the torus' surface with radial and vertical surfaces produced the inner leaf designs.
- The outer and entering leaves, as well as the interior dome, were designed using sphere latitudes and longitudes.
- Rather than the usual pattern of structural steel supporting components of the space frame, the Lotus Temple construction formwork was designed so that the panel is supported by timber joists.
- All the ribs and shells inside The Lotus Temple are made of white concrete up to the radial beam level.
- The lotus temple structure was built with a combination of white concrete of grade M30 to prevent shrinkage and expansions gaps.
- The construction of the temple flower petals was reinforced with galvanized metal to prevent rust stains and breakage and to maintain the clean appearance of this majestic architecture.
- The shells and arches of the Lotus Temple are clad with white colored Greek Marble panels that Marmi Vicentini S.P.A. applied to the surface and geometric designs.
- The lotus temple uses stainless steel brackets that are bolted into holes drilled after concreting, and the joints are filled with molded rubber bands and silicon sealant.

5 CONCLUSION

To summarize the paper's conclusion, it is evident that there are countless parallels between nature and architecture, some of which have been studied for centuries and others that are only now becoming significant as we work to heal the strained relationship between the built and natural worlds [9].

The society needs an environmentally safe building design strategy that does not jeopardize their necessities. While there are many strategies for individuals, few have been proven to be helpful on a larger scale. This is where biomimicry comes into the picture, providing innovative solutions to our challenges [10]. It ensures the integration of multiple disciplines for a design approach that is not only more valuable to its customers but also environmentally friendly.

Biomimicry as a design technique has the potential to improve society in the realm of architecture as well as human existence in general.

Rather than being employed as a technical technique of copying nature in a physical form, biomimicry should be used in a more holistic sense, where architects acknowledge the dynamic interactions that occur within the natural world and, more importantly, recognize our position within it. Nature is not simply a readily available source of inspiration since it is present in every molecule around us; natural forms have evolved within the same limits as humans, utilizing only the material and energy resources available on Earth.

As the humankind grows, we must cherish our future potential for advancement while still honoring our collective learnings of the past. As a result, establishing good building design methods for our descendants will become a feasible and meaningful goal.

REFERENCES

1. A. Y. E. s. Moheb Sabry Aziz, "Biomimicry as an approach for bio-inspired structure with the aid of computation," Alexandria Engineering Journal, pp. 707-714, 2016.
2. L. T. B. H. a. H. D. Lazaara Ilieva* Isabella Ursano, "Biomimicry as a Sustainable Design Methodology—Introducing the 'Biomimicry for Sustainability' Framework," Biomimetics (Basel)., 2022.
3. N. T. Buck, "The art of imitating life: The potential contribution of biomimicry in shaping the future of our cities," Environment and Planning B: Urban Analytics and City Science, pp. 1-21, 2016.
4. C. O. Francis Ogochukwu Okeke, "Biomimicry and Sustainable Architecture: A Review of Existing Literature," Journal of Environmental Management and Safety, pp. 1-15, 2017.
5. E. R. a. Z. K. Nathalie Verbrugghe, "Biomimicry in Architecture: A Review of Definitions, Case Studies, and Design Methods," Biomimetics, pp. 1-29, 2022.
6. A. A. P. M. A. e. Merhan Shahda, "Biomimicry Levels as an Approach to the Architectural Sustainability," Port Said Engineering Research Journal, pp. 1-9, 2014.
7. A. Y. E. s. Moheb Sabry Aziz, "Biomimicry as an approach for bio-inspired structure with the aid of computation," Alexandria Engineering Journal, pp. 1-8, 2015.
8. N. O. Gehan.A.N. Radwan, "Biomimicry, an Approach, for Energy Effecient Building Skin Design," Procedia Environmental Sciences, pp. 178-189, 2016.
9. E. J. a. Z. Vrcelj, "Biomimicry and the Built Environment, Learning from Nature's Solutions," Applied Sciences, pp. 1-19, 2021.
10. K. J. Rossin, "Biomimicry: nature's design process versus the designer's process," Design and Nature V, pp. 559-569, 2010.

Chapter 3

ILLUSIONISM IN ARCHITECTURE: AN EXPERIENCE

Asla Ashraf[1*] and Amisha Sinha[2]
[1]Assistant Professor, Delhi Technical Campus, Greater, India
[2]Student, Delhi Technical Campus, Greater Noida, India

ABSTRACT
Life is a collection of experiences that we encounter throughout our lives. Architecture is a thing that has existed in our lives since the beginning of time. In creating an experience, architecture is critical. This research paper examines how illusion can be used to persuade you to participate in an event in order to convey a story, as well as how it affects our psychology. Because humans see the world via their eyes, optical illusion plays a significant role in a variety of illusions. An optical illusion is a tool used by artists, historians, and architects throughout history to achieve perfection and aesthetics. We'll also learn about the aesthetics of optical illusion and how it's used in architecture.

Keywords: Illusionism, Optical Illusion, Forced perspective, Form Perception, Experience.

1. INTRODUCTION
To comprehend architectural illusionism, we must first comprehend what an illusion is. By providing a distinct illusion, architecture may address its own crises of spectacle. The optical illusion will be used to serve as a model for this endeavor. Illusionism would aid in the development of people's cognitive abilities by making spaces more appealing and allowing people to comprehend [1].

Space from various perspectives. Users of that space would also perceive space from their own understanding. This paper has been done to understand the process of building a built environment that had made an experience through various case studies.

2. BACKGROUND

2.1. Illusion and its Types
A misinterpretation of a "genuine" sensory input is an illusion stimulus, i.e., an interpretation that differs from generally accepted definitions of objective "reality." Everything is perfectly genuine; there are no illusions at all (Refer Fig 3.1). An illusion only arises when you are unable to perceive something completely; otherwise, it is not an illusion. We can distinguish illusions in three distinct ways, illusion as a philosophy, illusion as perception, and illusionism in architecture [2].

Figure 3.1 Illusion in Architecture
(***Source:*** Rethinking the future https://www.re-thinkingthefuture.com/)

There are Various Types of Illusions

The majority of illusions deceive the skin, hearing, and eyes, however other illusions can affect perception because of physical changes to the body's structure. Optical, auditory, and tactile illusions are the three basic categories of optical illusions [3].

1. Distortion Illusion

These are characterized by size, length, position, or curvature distortion. In the Ponzo illusion, the converging edges are interpreted as parallel receding lines in linear perspective, so the top line is displayed longer.

2. Pictorial Illusion

A sense of reality can be conveyed through illusionism in visual art. It has roots in Roman relief sculpture and wall painting. James Carter, Anna Eliza Hardy, William Harnett, Aaron Bohrod, John Singleton Copley, and Charles Rain are American artists who employed illusionism.

Architects use forced perspective to achieve a particular spatial effect in a designed space or building. Forced perspective tricks, along with other mechanisms such as digital post-production, are deliberately used by designers and commercial realtors to convince us that they are not real.

1. Forced Perspective

In architecture, a structure can be made larger, taller, farther, or otherwise by adjusting the ratio of objects to the viewer. Conversely, reverse engineering is sometimes used in classic garden designs and other styles to shorten the perceived distance to points of interest along the path.

2. Form Perception

Form perception is dependent upon the recognition of a figure from the background. Size, shape, and brightness constancies play an important role in perception. Visual Depth Perception depends on monocular and binocular cues.

2.1.1 Physical Manifestation of Illusion

The development and assessment of perceptual illusions has long been a successful strategy for studying cognition. Scientists are able to generate illusions when they investigate the sensations people are having and the brain regions that are interpreting the illusion. This subject is not just of interest to scientists.

Depth Illusion- Mario Ponzo originally demonstrated the depth illusion, often known as the Ponzo illusion, in 1911. The first dimension in which you perceive distance between others and yourself is depth. According to one theory, the human brain gauges an object's size based on its surroundings. (Refer Fig 3.2).

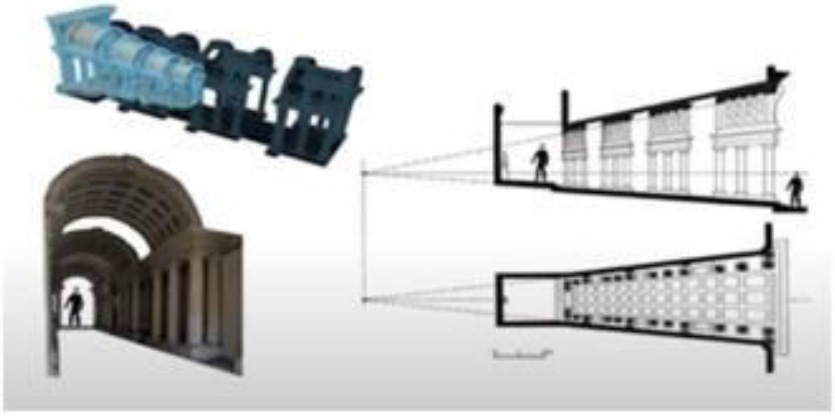


Figure 3.2 Implementation of depth illusion in built form (Source: theconversation.com)

We made stimuli that were matched in as many perceptual parameters as possible, but one did not qualify as a typical visual illusion. The phenomenal quality of being an illusion had significant effects on "Aesthetic Experience,""Evaluation", "Arousal" and "Regularity".

I. Greek architecture: The Parthenon, the ancient Greek temple of Athens, incorporates the concept of enhanced perspective. Objects in the distance have been magnified to match surrounding objects. The architect adjusted the ratio so that the temple looks correct from a distance of 6 times the height of the pillars (Refer Fig 3.3).

Figure 3.3T he Parthenon
(***Source:*** Greece is https://www.greece-is.com/)

II. **Baroque Architecture:** The Parthenon, the ancient Greek temple of Athens, incorporates the concept of enhanced perspective. Objects in the distance have been magnified to match surrounding objects. The architect adjusted the ratio so that the temple looks correct from a distance of 6 times the height of the pillars.

III. **Mughal Architecture:** An optical illusion of the door view of the Taj Mahal is not an extraordinary engineering effort. Instead, it's just an ordinary illusion. We all can observe this illusion by observing a distant object from a narrow opening. As we move away from the gate, the Taj appears larger to us (Refer Fig 3.4).

Figure 3.4: Illusion created on cupola (***Source:*** Google Images)

Impact on End User

Through all the above examples we realize the relationship between aesthetic and optical illusion very clearly. There is nothing like perfection exist in architecture but if we understand how we perceive a form or a structure we can establish perfection by using optical illusion. Aesthetic play important role in building experience, one will always remember an experience which is extra ordinary and illusions make things remarkable every time.

3. Case Studies

3.1 Case Study 1- Jewish Museum

The Jewish Museum Berlin presents the social, political, and cultural history of Jews in Germany from the 4th century to the present. It first welcomed visitors in 1999 present. The consequences of the Holocaust are openly discussed and incorporated into the museum (Refer Fig 3.5).

Three concepts that served as the museum's cornerstone informed the current design, which was developed in 1988, a year before the Berlin Wall fell. First of all, understanding Berlin's history would be difficult without acknowledging the enormous intellectual, economic, and cultural contributions made by Berlin's Jewish residents. The significance of the Holocaust must also be physically and spiritually ingrained in Berlin's memory and consciousness. Third, it is only via the inclusion of the Jewish people that their erasure and vacuum may be addressed. Through this case study, we understand the role of illusion in built form and its psychological impact on user. There are numerous elements in the museum which is not a direct expression of illusion but through the distorted form of museum and their planning techniques, it impacts their user psychologically. Architect understand the history and the context of building that museum and implemented it through its form which is an expressive tool to represent the Jewish lifestyle before, during and after the holocaust. All the incidents of history have been strategically put into the series then accordingly they planned itinto the built form so it can be experienced by the people. Refer Table 3.1-3.3 for more details.

Figure 3.5 Jewish museum (***Source :***) Google Images

Table 3.1 Project brief

Project	The Jewish Museum
Architect	Daniel Libeskind
Client	Government of Germany
Built in	1999
Area	15500 m2

Table 3.2 Justification Table

BUILDING TYPOLOGY	CASE STUDY	PARAMETERS	USER GROUP	OBJECTIVE
Museum	The Jewish Museum	Design concept Material used Construction techniques	Tourist, local public	To understand the aesthetic approach of building. To recognize different materials. To understand how people experience the space.

Table 3.3 Inferences table

PARAMETERS	INFERENCES
HOW IT IS BEEN CREATED?	Play of scale, weightlessness, distortion illusion, angles, light and shadow has been done to create an experience
MATERIALS AND CONSTRUCTION TECHNIQUES	Different materials like exposed concrete, zinc panels and color of materials are chosen to be dark and brutal which depict the dark past.
IMPACT ON END USER	A great psychological and sociological effect has been seen to be happen on end user. It make people feel and experience the whole journey through planning, concept and use of visual perception.

3.2 Case Study 2- The Comic Café

Green Café is a unique coffee shop located in Seoul, South Korea. Customers enter the store and are immediately immersed in a two-dimensional universe inspired by the popular Korean animated television shows W. Within the compact café, Even forks and knives are made to resemble two-dimensional images come to life, as are walls, counters, furniture, and other objects (Refer Fig 3.6)

Every object has a dark contour, and the matte white surfaces give the impression that the space was taken straight out of a cartoonist's sketchbook. Unsurprisingly, W. continues the narrative of a man who is imprisoned between our world and the reality of another cartoon. Every element of the room is flat-lined, from the chairs to the silverware, flattening the room into a two-dimensional plane and giving the appearance that the room is made entirely of paper and ink.

Through this optical illusion, each visitor would experience this space from their own perspective. They acknowledge and perceive the space with their own understanding. By giving this space a new perspective from other cafes it attracts more number of people and the craze for experiencing something new has increased the footfall and customers. Refer Table 3.4-3.6 for more details.

Figure 3.6 The comic cafe (***Source :)*** Google Images

Table 3.4 Project brief

Project	The Comic Cafe
Architect	-
Client	-
Built in	2017
Area	-

Table 3.5 Justification Table

BUILDING TYPOLOGY	CASE STUDY	PARAMETERS	USER GROUP	OBJECTIVE
Commercial building (café)	The Comic Cafe	Design concept Material used Construction techniques	Public	To understand the aesthetic approach of building. To recognize different materials. To understand how people experience the space.

Through this optical illusion, each visitor would experience this space from their own perspective. They acknowledge and perceive the space with their own understanding. By giving this space a new perspective from other cafes it attracts more number of people and the craze for experiencing something new has increased the footfall and customers.

Table 3.6 Inferences table

PARAMETERS	INFERENCES
HOW IT IS BEEN CREATED?	Play Of light and shadow illusion and depth perception
MATERIALS AND CONSTRUCTION TECHNIQUES	Non reflective matte finish material has been use so it wont reflect much light and create shadow. Black and white color are chosen to create 2d effect
IMPACT ON END USER	An exceptional psychological effect happen on end user. It make people feel and experience entirely different world.

3.3 Case Study 3- The Illusion

A video about Gangnam's morning rush. Building windows were obscured by a square wall, uninterested expressions, and elevator-waiting folks in black suits carrying matching briefcases.

While enduring the everyday routine, they daydream about a beach that seems like it's on their computer displays. Whilst going about their daily routine, they are daydreaming about a fantastical world. In the past, tower-style office buildings were exclusively constructed for usage. Monolithic structures cannot adapt quickly enough to haphazard cityscapes. To meet the new corporate culture, great effort has been made to design workstations that are different from the traditional box form. The majority of these initiatives, meanwhile, are made to advance the company's brand. This structure was created to break up the monotony of an office building where one may visit and take a break. Refer Table 3.7-3.9 for more details.

Table 3.7 Project brief (Location-Seocho - Go, Seoul, South Korea)

Project	The illusion
Architect	OBBA
Client	-
Built in	2018
Area	6636 m2

Table 3.8 Justification Table

BUILDING TYPOLOGY	CASE STUDY	PARAMETERS	USER GROUP	OBJECTIVE
Office building	The illusion	Design concept Material used Construction techniques	Office employee,	To understand the aesthetic approach of building. To recognize different materials. To understand how people experience the space.

In this project we understand the use of optical illusion created with different material to give the end user diverse environment in the monotonous office building. An office area has been created to think beyond boundaries. It also effects the urban environment which is merging the interior and exterior of the building.

Table 3.9 Inferences table

PARAMETERS	INFERENCES
HOW IT IS BEEN CREATED?	Play of light and shadow , scale and weightlessness are used to create an open space
MATERIALS AND CONSTRUCTION TECHNIQUES	Reflective mirror panel are used to create beach like experience Grey and exposed concrete panel has been used to maximize the sense of space.
IMPACT ON END USER	An exceptional psychological effect happen on end user. It make people feel and experience entirely different world.

3.4 Case Study 4- Mark's House by Two Islands

Another example of how mirrors deceive our eyes, seemingly lifting this particular structure into the sky without any support. Two Islands `Mark`s House` is a temporary pavilion erected in a parking lot in downtown Flint, Michigan to demonstrate the loss and importance of shelter. On the lower protruding surface of the upper volume are 882 lightboxes containing hundreds of photos from over 90 global Kickstarter backers. Refer Table 3.10-3.12 for more details

Table 3.10 Project brief (Location -Downton Flint, Michigan)

Project	Mark's House by Two Island
Architect	Two Island
Client	Michigan Flat Lot Competition
Built in	2013

Table 3.11 Justification Table

BUILDING TYPOLOGY	CASE STUDY	PARAMETERS	USER GROUP	OBJECTIVE
Pavilion	Mark's House	Design concept Material used & its construction. Reason of failure.	Public	To understand the concept behind and its practical approach To recognize different materials and how it can fails a project if not used properly To understand how people experience the space.

Through this project we recognize the application of illusion to create a concept and can made people experience it. Also people assimilate it through their own perspective and it generate a curiosity among the end user. There is also a fact that to execute these kind of illusion we should invest into correct material otherwise it will end up into big disappointment

Table 3.12 Inferences table

PARAMETERS	INFERENCES
HOW IT IS BEEN CREATED?	Play of light and reflection, merged with background.
MATERIALS AND CONSTRUCTION TECHNIQUES	Reflective mylam panel are used instead of mirror which results in failure.
IMPACT ON END USER	An exceptional psychological effect happen on end user. It make people feel and experience it differently.

Through this project we recognize the application of illusion to create a concept and can made people experience it. Also people assimilate it through their own perspective and it generate a curiosity among the end user. There is also a fact that to execute these kind of illusion we should invest into correct material otherwise it will end up into big disappointment.

4. CONCLUSION

Architecture is a medium through which we're designing for humans and building relationships via the alteration of spaces, this relation is made through experience with the assist of our

imagination and vision. Through imaginative and prescient, we will produce visual illusions in structure to create a brand new experience. Use of optical illusion isn't always new, if we examine current structure with the structure of the preceding eras, there may be a loss of the usage of optical illusion in current structure. Illusionism has a lot of scope to provide end users with an extraordinary experience. Proper understanding and execution can help tell stories that are not possible with other media. It can maximize the aesthetic value and perfection of the space to another level.

5 FUTURE SCOPE

Illusionism in architecture has been used for centuries to create perfection, aesthetics, and experience. Built-in structures, optical illusions, and vision play important roles in telling a story. Illusionism, whether visual or auditory, can be incorporated into architecture through technology to create new types of architecture, just as technology has taken over all aspects of society [4]. The best example is ARTECHOUSE, an innovative art space in the United States and a destination for immersive and interactive art exhibitions which is dedicated to exhibiting the works of new media artists [5].

REFERENCES

1. D. H. S. Hoda Yazdian, "Architecture and Illusion in the works of Sheikh Bahai," International Journal of Humanities and Social Science Invention, pp. 10-14, 2017.
2. A. Karaca, "Optical Illusion and Architecture," International Journal of Research and Analytic Reviews, pp. 606-613, 2021.
3. U. R. A. J. M. T. Seyed Vahab Hosseini, "Optically illusive architecture (OIA): Introduction and evaluation using virtual reality," International Journal of Architectural Computing, pp. 211-490, 2021.
4. J. Pallasmaa, "Architecture as Experience," Architectural Research in Finland, pp. 9-17, 2018.
5. H. Sağlam, "Re-thinking the Concept of “Ornament” in Architectural Design," Procedia - Social and Behavioral Sciences , pp. 126-133, 2014.

Chapter 4

ORNAMENTATION IN ARCHITECTURE

Pooja Thareja[1*] and Shreya Dubey[2]
[1]Assistant Professor, Delhi Technical Campus, Greater Noida, India
[2]Student, Delhi Technical Campus, Greater Noida, India

ABSTRACT
There is a constant argument of the need for ornamentation in architecture, whether it be Heritage ornamentation (Hindu, Islamic, and colonial) or contemporary ornamentation in the present day buildings (only exteriors) in Indian context. While some contend that heritage ornamentation needs to be revived in order to preserve traditional craftsmanship and prevent us from losing our traditional values. Others contend that contemporary ornamentation has to be enhanced since we are imitating global architecture in response to global impacts without taking into account the climatic conditions and requirements of the various regions of our nation. Functional as well as aesthetic ornamentation can be created with the proper guard of applications, workmanship, and technology. It is possible to design structures that are both functional and aesthetically pleasing thanks to improved technologies that allow for the quick fabrication of ornamentation. This book chapter emphasizes the value and necessity of ornamentation in the contemporary era of architecture.

Keywords: Ornamentation, Symbolism, Iconify, Building materials, Technology, Technical responsibility

1. INTRODUCTION
The Oxford English Dictionary's definition of "ornament" is an accessory, often utilitarian but occasionally also attractive or aesthetic. Despite being overly broad, the definition is nonetheless helpful for architecture. The fact that ornament in and of itself is not subject to criticism indicates a symptom in the area, and it suggests that the topic we should be asking is how ornament is used [1]

Consider the light switch, which is a key element of contemporary construction. When does it go from being functional to being ornamental, and at what point may it be acceptable to say that its decoration has trumped its function? The light switch is a crucial component that regulates the flow of electricity between wires to enable the on/off switching of electric lights [2]. A metal rod on a hinge which either joins the circuit or doesn't can be used to do this. Furthermore, it seems sensible to think that the switch should become effectively a closed box to prevent electrocution when fumbling for it in the dark. We now own a cover plate. However, what kind? Cover plates are frequently made of ornamental materials such as wood, plastic, metal, faux wood, stainless steel, and faux leather. Although one can argue that each has a different level of ornamentation, each essentially elevates the switch cover plate into the category of a piece that was created with both beauty and functionality in mind [3].

Whether ornament is applied or is a structural component, architects frequently make judgments involving ornament. Modernism promoted a minimal ornament aesthetic, but not one without adornment. There are numerous, not all equally valid, ways to produce ornament. For instance, Pier Luigi Nervi's decoration is structured and distinct. His designs are praised for the care he took with each structural component, but the sports halls he designed nevertheless include ornamental structures. It is not illegal [4].

Architecture's ornamentation is comparable to clothing's style. Although a burlap sack will do, clothing is still required. However, an Armani suit is considerably more appealing to wear and

admire. Fundamentally, clothing protects the body, but fashion improves how the body appears. Similar to how we might debate the aesthetics and calibre of clothing, we can also debate the attractiveness and proper use of adornment in a building. However, we cannot claim that the ornamentation is absent or that it is unlawful. It is essential, but building devoid of ornamentation is not.

2. LITERATURE STUDY

We discover numerous gorgeous buildings as we travel through the cities of Agra, Delhi, Jaipur, Calcutta and Mumbai, among others. Some of them are tombs, monuments, fortresses, temples, cathedrals, and mosques. Numerous of them were established prior to the time of Christ, while others did so subsequently. This architecture, which stands big and tall reminds us of that rich history that has been ours since several generations. This is due to the fact that ornamentation in architecture plays a significant role in Indian culture.

The distinguishing ornamental elements that characterize modern architecture were evolved over a lengthy period of time throughout Indian history. The towns of the Harappan Civilization, which are known for their innovative town design, contain the earliest and most striking examples of decoration in Indian architecture. Hindu, Jain, and Buddhist decoration styles are known to have existed in the post-Harappan period. The fusion of Persian and local architectural embellishment took place during the Middle Ages. After thereafter, India was exposed to Western decorative styles thanks to the colonial era. As a result, Indian ornamentation is a mix of native aesthetics and outside influences, which has given it a distinctive personality all its own [5].

Ornamentation in India can be divided into three categories, namely, Heritage; Contemporary; Contemporary and Heritage. Heritage ornamentation can further be subdivided into Hindu, Islamic, and Colonial.

2.1Heritage Ornamentation

Heritage ornamentation can be subdivided into Hindu, Islamic, and Colonial styles of ornamentation.

2.1.1. Hindu Ornamentation

Hindu Ornamentation can be categorized into Northern Hindu, Central Hindu, and Southern Hindu styles of ornamentation.

The characteristic shikhara, or superstructure, that characterizes the Northern Hindu architecture has extended to at least three to four different regions of northern India. The shikhara often has a rectilinear shape, while smaller rectilinear shikharas also exist atop the mandapas. The entrance gate of the sanctuary is typically ornately designed in a conventional Hindu temple in north India with representations of river deities and strips of figural, floral, and geometric adornment. The primary pictures of the deities are normally installed in niches sculpted on the major projections, while statues of mythical and semi-divine characters are frequently used to embellish the outside walls [6].

Chhattisgarh and Madhya Pradesh are located in central India. Early Chalukyan architecture dominated the Central Hindu Style. There are two different forms of architecture, structural and rock-cut. They employed locally accessible reddish golden sandstone for their construction. The process of building a structure by carving it out of a single mass of natural rock is known as rock-cut architecture. The continuous frieze of Ganas in numerous playful poses carved in relief on each pedestal is a prominent aspect of these cave temples. The cave temples' front verandas are very basic, but their interior halls are loaded with abundant sculptural symbology. A number of structure temples were also erected by the Chalukyans at Badami, furthermore to the rock cut cave temples. The early Chalukyans merged elements of the existing south and north Indian

building styles to produce their unique decoration and building techniques. Elevated platforms, pithas, ornate door frame, plinth mouldings, etc. are some of the characteristics of these temples. Lad Khan Temple and Durga Temple in Aihole, and Malegitti Shivalaya in Badami are a few examples.

Dravidian architecture is another name for the South Hindu Style, which developed in the southern region of the Indian subcontinent. It is mostly made up of temples with pyramid-shaped towers made of granite, soapstone, or sandstone. It has a short neck, a pyramid-shaped tower with progressively smaller levels of tiny pavilions, and a dome known as a shikhara on top. The multiple storeys give the southern design a horizontal visual lift. The superstructure atop the sanctuary is made up of a pyramidal arrangement of progressively lowering storeys. A parapet of tiny shrines, square at the corners with barrelvault roofs in the middle, separates each story. The choice and placement of the stone-carved deities on the exterior walls and the interior, as well as the variety of decorative features that are occasionally so extensive as to almost conceal the underlying construction, are less evident contrasts between the two primary temple kinds. The temple's outside walls are divided by pilasters and have niches that house sculpture.

2.1.2 Islamic Ornamentation

Various ornamentation techniques applied to Islamic architecture, include stalactite (or Muqarna design), geometric designs, arabesque, calligraphy, finials, purna-kalasha, star of David, inverted lotus, chevra, glazed tiles, stucco and mosaic. Stalactite or Muqarana design is a honeycomb motif made up of a collection of tiny, arching cells stacked one atop the other, diminishing its height [7]. The area at squinches is filled with this pattern to provide greater support for the upper portion. Example is Qutub Minar. In particular, Mughal-era structures had geometric designs (stars, square, stars, etc.) on the dome's drums, the façade, the spandrels, and the flooring of the principal chambers. Many medallion designs, such as an arabesque pattern, a circle, an inverted lotus, etc were used.

Arabesque is the primary Islamic style of ornamentation that features intertwined stems and lines. The lines are smooth and sharp, flat or curved, and never separated. The Qquwwat-ul-Islam Mosque's main screen hosted the first attempt in India. Calligraphy has been engraved in low relief and inlay work on the monuments. The inscriptions are inscribed in several scripts in both Persian and Arabic. The inscriptions on the monuments are made in such a way that the size of the lowest and highest band look identical as the size is rising upward [4].

The buildings' domes include magnificent finials that depict purna-kalasha, lotuses, etc. one on top of the other and are made of metal, marble, or stone rubble masonry. Purna-kalasha is a representation of creativity and abundance. This Indian design was borrowed by the Mughals, who incorporated it onto their structures. This can also be seen on the bottom and top of Mughal-era columns. Star of David is a six-pointed star formed by the union of two triangles. It is an old astrological symbol used in India that stood for power and is crucial for carrying out all religious rites. Most Islamic structures have it embellished at the spandrels of the arch, such as Humayun's tomb, Delhi Old Fort, Fatehpur Sikri, etc.

A traditional Hindu and Buddhist emblem, the inverted lotus symbolises the principle of growth. Because gods don't rest on the ground, it also served as a representation of a god's seat. It was often applied to buildings during the Mughal era in India, both in blooming and inverted forms. The mihrab of the Illtumish Tomb has a flowering lotus shape, and its inverted version was likely built for the first time in India at Jamali Kamali Mosque. It was thereafter utilised in white marble and red sandstone at Humayun's tomb, the Delhi Old Fort, Fatehpur Sikri, and other locations. The Mughals in India adapted the Persian architectural embellishment known as

chevran (zigzag pattern). The nookshafts and columns at the Taj Mahal, Humayun's Tomb, and Akbar's Tomb all feature this design.

Glazed tiles were employed because, unlike unglazed tiles, which enable liquids to leak out and shorten building lifespans, glazed tiles are impervious to liquids. Stucco is a lime plaster that comprises lime stone powder and is applied extremely thickly to walls or ceilings to create low relief paintings with incised surfaces. The basic goal of stucco work is to create a smooth, plain surface for successful results. The statues at spandrels, intrados, pillars of the arches, and ceilings have typically all been stuccoed. Mosaic, or in lay work, is a specialised form of ornamentation in which fragments of various materials, such as glazed tiles, semi-precious stone, glass, etc., in a variety of colours, are set into blocks or stabs of stone or marble with their faces facing downward in order to fill in any gaps or voids in the design. The Taj Mahal, the Tomb of Akbar at Sikandra, and Humayun's Tomb all display this artwork [3].

2.1.3 Colonial Ornamentation

Ornamentation during the Colonial period can be classified into four categories, namely, British, Portuguese, French, and Dutch.

A substantial marble structure in Kolkata, called the Victoria Memorial is an excellent example of British style of ornamentation. The Angel of Victory stands 16 feet (4.9 metres) tall above the Victoria Memorial's main dome. Allegorical statues depicting architecture, art, charity and justice are positioned around the dome, and prudence, motherhood, and learning are shown above the north porch. The Victoria Memorial was constructed with white Makrana marble, just like the Taj Mahal. With its dome, four subsidiary, octagonal domed chattris, tall gateways, and domed towers at the corner, it is reminiscent of the Taj Mahal [8].

Goan Portuguese Homes represent the Portuguese style of ornamentation from 1498 to 1961. These residences had unusually big decorative windows that opened onto verandas and faced the street. Bright colours were used to paint homes made of natural and vegetable dyes, giving them a unique identity and making it possible for sailors to identify them from the water. In contrast to the Hindu-styled homes, the sheltered verandahs and porches were made for mingling. Front doorways were lined with ornamental railings and columns that were frequently used in adornment. Compound walls and Gateposts were intricately carved.

Franco–Tamil houses depict the French style of ornamentation from 1673 to 1954. A transition in architectural styles can be seen in the facades of two-story buildings, where the bottom level is typically of the Tamil type with tinnai, talvaram, and carved doors, whereas the first floor exhibits French influence with plaster decoration, arched windows, fluted pilasters, columns with capital, architectural embellishments such as door mouldings influenced by French patterns, as well as floral decorations such as acantha leaves, resulting in a fusion of Tamil and French ornamentation styles. Roofs were covered in tiles. Elaborately carved entrance doors include complex frames constructed of multiple wooden layers. The front shutter, which has a carved cutout, and the back shutter, which is plain, are thick and frequently made of two pieces. Iron hinges hold the doors to the frames. The carving style on these doors is very consistent. Symbols representing the owner's community may be seen in the relief at the head of the door frame.

Kerala's Mattancherry Palace having an understated yet opulent exterior with white front walls and sloping roof is an example of Dutch style of ornamentation from 1605 to 1825. Additional signs of European influence in the palace are the long, expansive halls, arches, etc. Due to its pyramidal shape and clay tile roof, which slopes downward from the peak of the roof on all sides, the building has a classic appearance. The wood works on the windows and doors are done with exceptional craftsmanship.

2.2 Contemporary Ornamentation

Many architects working today (1994–present) are attempting to redefine the word "ornament." Ornament can now be considered as an integrated and functional architectural component that is influenced by building materials and technology/techniques, as opposed to being seen as additive. Additionally, it is responsible for technical duties like energy conservation, temperature control, and daylight modulation. The visual impact and overall expressive aspects of a modern structure, and more particularly, a modern architectural facade, are enhanced by affective and aesthetic factors. The superficial uses of earlier architectural styles are rejected by contemporary decoration, which simultaneously aims to iconify and symbolize. The form of the building is also impacted by modern ornamentation.

2.2.1 Building Materials

The various building materials used for contemporary ornamentation include steel, aluminium, glass, concrete, bricks, wood/timber, stone, tiles and boards.

Steel is available with a variety of finishes, including perforated, mirror, hairline, texture, and custom designs. Its benefits include its pleasing aesthetics, toughness, resistance to flame and corrosion, termite resistance, and versatility in carving. In environments with high humidity, it is a suitable choice. However, frequent maintenance and its propensity to rust (apart from rust resistant types like galvanised steel) must be taken into consideration. The two main types used are mild and stainless steel. But for cladding, mainly mild steel is employed.

Solid aluminium, aluminium composite panels (ACP), and extruded aluminium are all employed as wall cladding in the case of aluminium. They have an excellent strength-to-weight ratio, are recyclable, light in weight, and offer a variety of finishes and colours. ACPs are also available in a variety of styles, including acrylic-based, brush-faced, mirror-faced, wood-textured, marble-faced, and mirror-faced. The cladding on facades, walls and column coverings is made of extruded aluminium. Aluminum is outperformed by steel in regards to strength.

The adaptability, beauty, capacity to blend boundaries, visually increasing a space, and allowing natural light, makes glass a very frequently employed material in building façades. Impact-resistant glass, burglar-resistant glass, safety glass that is enamelled and laminated, lacquered glass, and even ceramic-printed glass are available today. Glass has also improved acoustical quality, and one can now see panels of glass with incorporated louvres that can direct sunlight as required.

Glass fibre reinforced concrete, or GRC, is a cladding material that can be utilised for residential, commercial, industrial, and institutional purposes. They are simple to install and maintain, and they don't need to be painted or plastered because they may be fixed directly on top of masonry or brickwork.

A long-used, less expensive alternative is brick cladding. It resists water and can be visually appealing due to the diversity of patterns that it can develop into. The dry type of construction sans mortar is also available overseas.

The inherent resistance to decomposition makes a wide variety of wood species excellent external cladding material. Because wood is a lightweight material, hefty brick outside walls are eliminated, which reduces the size and consequently the expense of foundations. Other advantages of wooden cladding include its availability in a variety of softwoods, hardwoods, and engineered woods, the capability of the panels of to be pre-fabricated, excellent heat and sound insulation, and ease of maintenance. They have a calming aesthetic, come in a variety of textures and treatments, and are better for the environment because timber is a sustainable material.

Natural and environment-friendly materials include stone. Along with stone veneers, alternatives include slate, granite, sandstone, marble, Kota stone, and limestone. There are also widely available particular stones like Jaisalmer stone, Jodhpur stone, etc. Similar to all other materials, correct installation is crucial to prevent leaks from occurring, especially in areas with heavy rainfall. The durability of stone cladding depends on its thickness; the thicker it is, the more durable it will be. Stone cladding has enduring durability without the need for painting, a timeless appearance, and customizability but requires a large initial expenditure. Additionally, one observes the use of mosaic stones with a delicate texture and long-lasting gloss.

Numerous materials (granite, concrete, brick, ceramic, glazed tiles, stainless steel, marble) and designs are available for tile cladding (strip, rustic, wave etc). Weather-resistant granite tiles are suitable for both interior and exterior use, in contrast to concrete tiles, which can be used in non-load-bearing and load-bearing walls. Although pricey and often requiring more upkeep, marble tiles continue to be the most desirable. Low water absorption makes vitrified ceramic tiles ideal for cold climates, and they also resist corrosion and staining. Bathrooms often use mosaic cladding tiles because they are quick to dry.

Today's market offers gypsum, compressed cement, calcium silicate, fibre cement, e-boards, and even environmentally friendly boards. Their finishing can be in a variety of ways. Laminates continue to be a great choice for interiors. High pressure laminates are being employed in settings like hospitals where cleanliness is crucial to prevent the spread of hazardous microorganisms.

2.2.2 Technical responsibilities such as daylight modulation, temperature control and energy conservation

The technical responsibilities provided through ornamentation can be understood through two examples. Firstly, the Crescent Office Block in Surat, designed by Mumbai-based architect Sanjay Puri has overlaying angled fins that are covered in pre-rusted steel. The building's distinctive orange colour is a result of the weathering steel used to cover each fin—a pre-rusted metal frequently referred to by the brand Corten. The angular shape is a direct reaction to the strong sun, which causes extremely high temperatures for a large portion of the year. The curved wall opens up to make room for a number of stacked north-facing windows while acting as a shelter from the southern sun. In order to minimise heat uptake and the effects of the east and west sun, the walls are inclined and projected. Secondly, Jaipur's Pearl Academy of Fashion represents the architecture which is a fusion of contemporary adaptations of classic Indo-Islamic architectural features and passive cooling techniques used in Rajasthan's hot, dry desert climate. A dual skin that is taken from the Jaali, a traditional construction component that is common in Rajasthani architecture, protects the structure from the elements. The dual skin serves as a heat barrier separating the structure from its surroundings. Through fenestrations, the outer skin, which is 4 feet away from the structure lessens direct heat gain. The Jaali's inner face has drip channels that promote passive evaporative cooling, which lowers ambient temperature pf the wind.

2.2.3 Symbolism

To denote frequently used features and components that have evolved through time, an architectural symbology is used. One needs to have a solid understanding of exactly what the symbols on a drawing mean in order to quickly interpret an architectural design. Symbols are intended to simulate a fixture, material or component's appearance. There are countless varieties of symbols. The window, door, and electrical symbols are a few of the symbols that are more frequently seen on a construction design. Similar to that, ornamentation can serve as a way to symbolically depict many kinds of things. Hyderabad's Fisheries Department building is an example for symbolism. The 4-story fish building, built in 2012 serves as a National Fisheries Development office. Technology development for India's aquaculture and fisheries is being

carried out inside the massive flounder. A silver fin serves as the building's entrance. With its distinctive architecture, the fisheries department headquarters sticks out amid the Hyderabad skyline.

2.3.4 Iconify

A symbol or depiction that symbolises anything through analogy or likeness is known as an icon. Buildings are frequently envisioned as icons that reflect the collective image since they are physical objects that are visible from afar. When it comes to scale, these icons can be used to represent a neighbourhood, a city, a region, or even an entire nation. However, when it comes to values, they can have political, temporal, technological, socio-cultural, or even religious implications. Because ornamentation gives a building a distinctive appearance that is recognisable to the public, it serves as an icon for a location that can be anywhere from a tiny town to a rural area. Lotus temple in New Delhi as an example to better comprehend this. The temple's shape, which resembles a floating, half-opened lotus flower encircled by its leaves because of ornamentation in the shape of a semicircle, has made it an icon of New Delhi. Panels of white marbles are used to cover the outer and inner surfaces of the shells and the arches. These marble panels are fastened to the surface of concrete using anchors and brackets made of stainless steel.

2.3.5 Form Derived Due to Ornamentation

Delhi Land & Finance (DLF) constructed the Gateway Tower in Gurgaon, which is an appropriate example of form derived due to ornamentation. It earned the title “Titanic” due to its shape and size, which were a result of ornamentation. This building's well-known architect is Hafiz Contractor. It serves as a gateway to Gurgaon and represents corporate employees and FDI from abroad.

2.3.6 Form Uplifted by Ornamentation

Hafeez Contractor designed Infosys multiplex in Mysore, India, exhibits numerous design and architectural accomplishments and resembles a massive golf ball. The weekend movie theatre, which has four screens and is housed in a geodesic dome, also hosts a number of other events, including the initiation of fresh classes of trainees. It covers 1.44 million square feet and is regarded as the campus's centrepiece in Mysore.

2.3Contemporary and Heritage Ornamentation

In the quest for ornamentation styles that are in line with Indian traditions but sensitive to the many needs of current Indian culture, there are many examples of ornamentation that point to a mature and nuanced approach to using history. However, it would be oversimplified to think that a loose connection between the present and past would inevitably result in ornamentation that successfully combines tradition with the needs of a culture that is fundamentally conservative while also being dedicated to materialistic and industrial growth **[35]**. As a result, ornamentation styles that are both traditional and contemporary have emerged. The change in technology and materials is what distinguishes heritage ornamentation from contemporary ornamentation. Replicas of heritage ornamentation and inspiration drawn from heritage ornamentation are two ways to achieve current ornamentation in this category.

2.3.1 Technology and Materials

The difference between contemporary-heritage ornamentation and heritage ornamentation can be understood through an example that highlights the change of technology and materials.

In Sun Temple at Konark, an example of heritage ornamentation, the complete ceiling is reinforced with iron grid to withstand the weight of the enormous kalasa over the pida. The stones are placed in ashlar masonry and the individual stones were chiseled and smoothed to make the joints less obvious. These stones were firmly set on top of one another owing to their self weight and the addition of iron dowels to secure their placement. The construction of the

temple was mostly done with the khondalite stone type, but the doorjamb as well as few sculptures were done with high-quality chlorite. The laterite stones were mostly used in the construction of the temple's internal core and other components. The use of khondalite, which is easily weathered and subject to chemical change, was a significant factor in the temple's slow collapse.

In Akshardham Temple, New Delhi, an example of contemporary-heritage ornamentation, the entire structure is made of Italian Carrara marble and pink sandstone from Rajasthan. There is no ferrous metal used in it. As a result, it is not supported by concrete or steel. The spiritual structure consumed 6000 significant light red sand rocks in all. This cutting-edge method guarantees that the shrine will last for a full thousand significant years.

2.3.2 Replica of Heritage Ornamentation

The Le Meridien Pune, a breathtakingly beautiful five-star hotel, is an architectural expression in Rajasthani style that combines traditional elegance with a dash of modernity.

2.3.3 Derived inspiration from Heritage Ornamentation

Corporate office headquarters at Jaipur designed by architect Sanjay Puri is an example of ornamentation derived through inspiration from heritage ornamentation.

3. Case Study

This section includes 3 live case studies and 7 secondary case studies.

3.1Live Case Studies

The three live case studies covered include the study of Bara Imambara, Lucknow; Rumi Darwaza, Lucknow; and Pioneer House, Delhi.

3.1.1 Islamic

Bara Imambara, built in 1784 by Asaf Ud-Daula, the Nawab of Awadh is located in Lucknow, Uttar Pradesh, India. It represents the Islamic (Mughal) style of ornamentation. It was constructed to aid the famine-stricken populace. It is now a significant Nawabi religious structure where the holiday of Moharram is observed, services are held to remember Ali and Hussain's deaths during the appropriate season, and it occasionally serves as a mausoleum for the founder's family. Refer Table 4.1 for parameter details.

Table 4.1 Parameters for Bara Imambara

PARAMETERS			
Heritage ornamentation	**Symbolism**	**Technology**	**Building Material**
Islamic (Mughal) style	Culture- Ornamentation elements (vaults, geometric design, cusped arches, purnakalasha, jharokhas, corbels, etc) symbolize influence of Islamic culture.	No central dome or minarets. No beams or pillars. Weight balanced by corridors, arched doorways and windows with multiple small domes.	Rubble or coarse concrete of bricks and mud. Rice husk. No woodwork or metal.

Rumi darwaza, built in 1784 with a height of 18m is located in Lucknow, Uttar Pradesh, India. A grand entrance, constructed with the support of Nawab Asaf Ud-Dowlah, it is one of India's most stunning architectural creations. It represents Islamic ornamentation style (Mughal). Refer Table 4.2 for parameter details.

Table 4.2 Parameters for Rumi Darwza

PARAMETERS			
Hindu Ornamentation	**Iconify**	**Symbolism**	**Building material**
Islamic (Mughal) style	Finest gateway built in Lucknow. Logo for city of Lucknow.	Culture- Ornamentation elements (Minarets, chhatris, recessed and cusped arches, lotus petals, floral motifs, turrets with floral patterns, octagonal bastions) symbolize influence of Islamic culture.	Lakhuri bricks. Thick lime plaster.

3.1.2 Contemporary

The Pioneer House in Karol Bagh, New Delhi, India is designed by Anagram Architects. The project covering an area of around 1400 sqm was completed in 2014. This building serves as an office for "Pioneer Publicity Corporation Private Limited". Refer Table 4.3 for parameter details.

Table 4.3 Parameters for Pioneer House

PARAMETERS				
Contemporary Ornamentation	**Symbolism**	**Building material**	**Technology**	**Technical responsibility**
Form uplifted by ornamentation	Signage-Façade symbolize company logo. Form- Form of building symbolize extruded or projected profile of thumb.	Red aluminium perforated screen.	Pattern of logo articulated by reattaching stamped-out discs through a pivot detail.	Daylight modulation - Skin of louvers diffuse natural light with the workspace.

3.2 Secondary Case Studies

3.2.1 Heritage

The Sun Temple of Konark was built in the 13th century to honour the sun god Surya. Refer Table 4.4 for parameter details.

Table 4.4 Parameters for Sun Temple

PARAMETERS			
Heritage ornamentation	**Symbolism**	**Building materials**	**Technology**
Hindu style	Form- Temple conceived as a huge and colossal chariot drawn by team of seven horses in galloping mode. Sculptures-12 wheels symbolize twelve months of the year, other sculptures symbolize Sun god, dancers, elephants guarding entrance, soldiers, hunting ofanimals,	3 types of stones used: Khondalite stone type used largely. High quality chlorite for doorjamb and some sculptures. Laterite stones.	Entire ceiling strengthened with iron grid. Stones laid in ashlar masonry. Stones placed on one another firmly, supplemented by use of iron

	lotus petals, military marches, etc. Culture- Sculptures symbolize strong influence of Hindu culture.		dowels.

Chhatrapati Shivaji Terminus located in Mumbai, Maharashtra, India was constructed in 1888 with a cost of around 2,013.4 million. It was designed by architect Frederick William Stevens, Axel Haig. Refer Table 4.5 for parameter details.

Table 4.5 Parameters for Chhatrapati Shivaji Terminus

PARAMETERS			
Heritage Ornamentation	**Symbolism**	**Iconify**	**Building material**
Colonial style	Culture- Ornamentation elements symbolize meeting of Gothic (3D-stone carvings of local species of animals, flora and fauna, arched tympana, portrait roundels of human faces, stone mesh works on the decorated rose windows, gargoyles,etc) and traditional Indian (stone dome, turrets, pointed arches , etc) cultures. Sculptures- Lion symbolizes the United Kingdom, peacock and tiger symbolize India	Iconic symbol of Mumbai	Local yellow malad stones. Italian marble. Polished granite. White limestone. Burma teak wood. Steel.

3.2.2 Contemporary

The office building of Infosys in Pune, India designed by architect, Hafeez Contractor is an example of form derived due to ornamentation. Refer Table 4.6 for parameter details.

The Motisons Tower in Jaipur, India was designed by architect Kothari Associates in 2013. It is a building with an area of 50,000 square feet designed for a renowned high profile jeweller in Jaipur. Refer Table 4.7 for parameter details.

Table 4.6 Parameters for Infosys Pune

PARAMETERS				
Contemporary Ornamentation	**Iconify**	**Symbolism**	**Material**	**Technology**
Form derived due to ornamentation	Iconic element in the cityscape of Jaipur. Not regional but international. Transformed the face of architecture in India	Form- Symbolizes lotus. Colours- 9 special coloursused symbolize colours of natural gem stones	Coloured glass- clear reflective from outside, clear glass with acid washed internal surface from inside. Coloured gold mouldedfibre glass. LED wall washers	Glass facade is second skin to main structure supported by SS spiders. LED wall washers wash internal surface of glass and create millions of colors at night

Table 4.7 Parameters for the Motisons Tower

PARAMETERS					
Contempor-ary Ornamenta-tion	**Symbolism**	**Iconify**	**Building material**	**Technology**	**Technical responsib-ility**
Form derived due to orname--ntation	Form- Egg shape of building symbolizes concept of evolution	An example of architectural excellence for future Iconifies state of the art of construction techniques and the functional values of design	Internal structure- Reinforced cement concrete, brickwork Outer shell- Steel 450 MT, glass and aluminium	Aluminium and glass cladding in steel frame shell Structure stands away from steel shell	Solar passivization Energy conservation

Contemporary and Heritage Ornamentation

Chhatrapti Shivaji International Airport Terminal 2 Building in Mumbai was designed by the architectural designer, Skidmore, Owings & Merrill (SOM). It covers an area of 210,000 square metres and was constructed with a cost of nearly ₹98 billion. Refer Table 4.8 for parameters.

Table 4.8 Parameters for Chhatrapti Shivaji International Airport Terminal 2

PARAMETERS					
Contemporary & Heritage Ornamentation	**Symbolism**	**Iconify**	**Building Material**	**Technology**	**Technical responsibility**
Derived inspiration from heritage ornamentation	Form- Symbolic of traditional Indian pavilions. Colour- Symbolic of national bird of India, peacock. Culture- Ornamentation elements symbolize regional patterns and textures	A new global, high-tech identity for Mumbai Celebrates both India's rich cultural heritage and country's increasingly global future	Glass fibre reinforced gypsum panels. Coloured glazing. Glass wall with gridded cable frame.	Modular construction. Modern cutting edge strategies	Temperature control. Daylight modulation

The headquarters for clothing sourcing company in Triburg, Gurgaon was designed by an Indian architecture firm called SPA Design. Refer Table 4.9 for parameters.

Awadh Shilpgram designed by Archohm (Architecture Studio) is a traditional Indian-inspired crafts hub for exhibiting crafts in the Indian city of Lucknow, complete with a collection of grass-roofed studios and a spiraled shopping area. Refer Table 4.10 for parameters.

Table 4.9 Parameters for Headquarters for Clotjing Sourcing Company, Gurgaon

PARAMETERS				
Contemporary and Heritage Ornamentation	**Symbolism**	**Building Material**	**Technology**	**Technical Responsibility**
Derived inspiration from heritage ornamentation	Form- Symbolic of Adalaj stepwell	Brick Concrete	Structural arches Concrete columns supporting vaulted ceiling	Daylight modulation

Table 4.10 Parameters for Awadh Shilpgram, Lucknow

PARAMETERS		
Contemporary and Heritage Ornamentation	**Symbolism**	**Building Material**
Derived inspiration from heritage ornamentation	Form- Symbolic of chaotic composition of urban bazaars Culture-Arches symbolic of culture of architecture in Lucknow, patterns on jaalis symbolic of culture of traditional Chikan embroidery	Red Agra sandstone

4. CONCLUSION

Architectural ornamentation has been used throughout history, in both contemporary and historical periods as well as a combination of both. It has never been completely neglected or ignored because it has always been used to embellish buildings in some way. Any building's ornamentation is the most significant indication that draws attention and contributes to iconifying it. Ornamentation, which can be used to reflect signage and the history and culture of a place through sculptures, shapes, and colors, is a necessary component of architectural expression. The level of craftsmanship, technology, construction materials, technical characteristics, and ornamentation applications are key elements in establishing ornamentation's significance in architecture.

REFERENCES

1. H. Sağlam, "Re-thinking the Concept of “Ornament” in Architectural Design," Procedia - Social and Behavioral Sciences, pp. 126-133, 2014.
2. A. Garg, "Evolution of Architectural Ornamentation A comparison between ancient and modern era (1900-2020)," Research Proposal, pp. 1-8, 2020.
3. N. I. Morehouse, "Condition-Dependent Ornaments, Life Histories, and the Evolving Architecture of Resource-Use," Integrative and Comparative Biology, pp. 591-600, 2014.
4. A.-M. Sankovitch, "Structure/Ornament and the Modern Figuration of Architecture," The Art Bulletin, pp. 686-717, 1998.
5. H. Y. W. Ayu Ratna Pertiwi, "Evolution of Hindu–Buddhist Architectural Ornaments into Javanese Traditional Architecture: Case Study of Sewu Temple," Proceedings of the 4th International Conference on Arts Language and Culture, pp. 119-219, 2020.
6. J. Shafiq, "Architectural Elements in Islamic Ornamentation: New Vision in Contemporary Islamic Art," Arts and Design Studies, pp. 11-21, 2014.
7. D. G. A. S. Fawzia Irhayyim Hussein, "Ornamentation and Modern Architecture in Iraq," Journal of Engineering, pp. 115-122, 2019.
8. J. Zilhão, "The Emergence of Ornaments and Art: An Archaeological Perspective on the Origins of “Behavioral Modernity”," Journal of Archaeological Research, pp. 1-54, 2007.

Chapter 5

REVIVAL OF ABANDONED INDUSTRIAL BUILDINGS VIA ADAPTIVE REUSE

Tanya Gupta[1*] and Jatin Rawat[2]
[1]Professor, Delhi Technical Campus, Greater Noida, India
[2]Student, Delhi Technical Campus, Greater Noida, India

ABSTRACT
As times change, the need for various types of spaces diminishes. These buildings, whose function is no longer required, become subjects of abandonment. In many situations, the types of buildings most likely to be forgotten include industrial buildings, political buildings, and community buildings. One of the possible lifelines for such buildings is adaptive reuse as it reaffirms their presence in the neighborhood. By doing so, one less building is added to the urban fabric and there is a lesser negative impact on the environment. It is natural that Industrial buildings become redundant for many reasons, such as changes in economic and industrial practices, cost of maintenance, and people's perceptions. Most of these buildings are no longer suited for their original function and a new use has not been decided for them. Adaptive reuse enables the conversion of existing, obsolete Industrial buildings and sites into new, mixed-use developments that will play an essential role in enhancing local communities.

Keywords: Industries, Adaptive Reuse, Benefits, Factories, Abandoned.

1.INTRODUCTION
Adaptive reuse refers to the process of reusing an existing building for a purpose other than which it was originally built or designed for. It is also known as recycling and conversion. Revitalizing the existing built fabric by finding a new use or purpose for obsolete buildings can be a wonderful resource to a community by "keeping neighborhoods occupied and vital" [1].

Recycling has become second nature to modern communities as we strive for environmental sustainability. A structure straightforwardly utilized in assembling or in fact useful endeavors. Industrial Buildings are not for the most part or commonly open to other than laborers. Adaptive reuse in architecture denotes the process of building conversion to accommodate new functional requirements [2]. The possibility of Adaptive reuse of structures to produce space for new useful fundamentals is neither something new or contemporary nor is it restricted to engineering. It has been applied to practically a wide range of curios.

Adaptive reuse is seen as an effective way of reducing urban sprawl and environmental impact. Through adaptive reuse old, unoccupied buildings can become suitable sites for many different types of use. Adapting a building is sustainable at the most fundamental level, and it also helps preserve the urban context while adding richness and vitality. Adaptive reuse is a solution that maintains the character of the building while not compromising on its functionality and integrity.

Constructing a building from scratch takes up a lot of time, in this fast pace world time has the most value. Reusing a constructed building helps in saving time. In India the cost of construction drastically increased in past few years because of huge urban sprawl. Adapting an industrial building will help in lower construction cost. Industrial Buildings takes up a large area of land, so after their abandonment those huge areas are left vacant with no future scope; here Adaptive Reuse can take a part for a sustainable approach to revive those buildings.

Keeping the above situation in mind the basic aim is the Strategic use of site-sensitive design for Industrial structures which can contribute to physical life improvements, impact social behavior, and contribute to lifestyle enhancements within the community. The following objectives are

fulfilled in this chapter: (a)To study the concept of Adaptive Reuse, its components and design elements (b)To explore various theories pertaining to Adaptive Reuse for Abandoned Buildings (c) To study incorporation of Adaptive Reuse on Industrial Buildings that seeks to reduce Urban Sprawl and Environmental Impacts (d) To analyze the feasibility, design considerations and success of Adaptive Reuse on an Abandoned Building (e) To provide with ways of providing the much-needed sensitive approach in adaptive re-use, while making minimum interventions and alterations, making them function able for contemporary times.

2. LITERATURE REVIEW

2.1 Industrial Buildings

Includes a building or part thereof wherein products or material are fabricated, assembled, or processed such as assembly plants, laboratories, power plants, refineries, gas plants, mills, diaries and factories. Refer figure 5.1.

Figure 5.1 TATA Jamshedpur Industries (***Source:*** Google Images)

2.2 Importance of Industrial Buildings

Following focuses draw out the significance of industry in an economy:

- **Structural Transformation:** Industrial improvement achieves underlying change in the economy. It implies that the reliance of our economy on horticulture will be decreased.
- **Source of Employment:** Huge talented labour force which is as yet jobless. foundation of industries which can produce work valuable open doors for a huge scope.
- **Enhancing further the Economic Growth:** As industrialization advances, the capital merchandise industry additionally begins to thrive. This aides in additional financial development and encourages industry and development.

2.3 Indian Industrial Regions

India has several industrial regions like Mumbai- Pune cluster, Bangalore-Tamil Nadu region, Hugli region, Ahmedabad-Baroda region, as shown in the figure 2 Industrial Regions in India. Refer figure 5.2 & table 5.1

ISBN: 978-93-93810-64-9

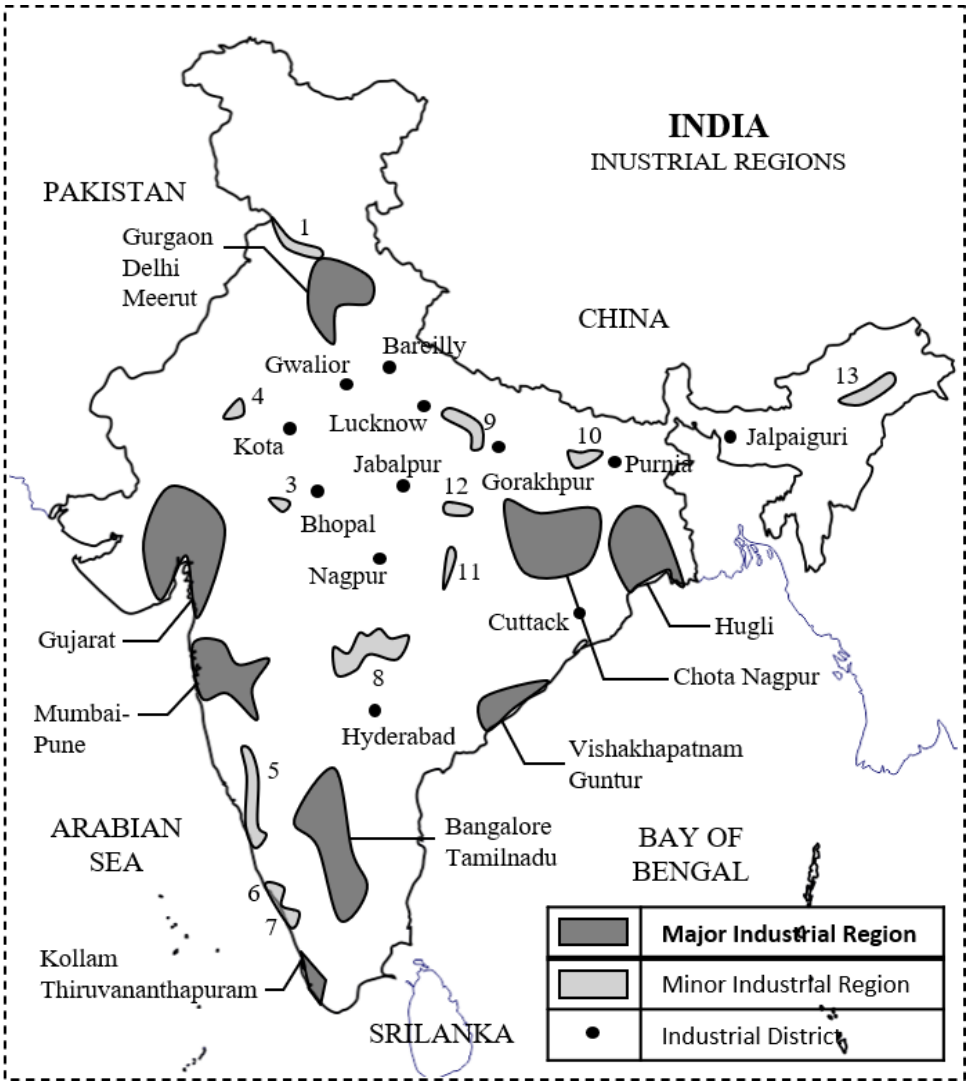


Figure 5.2 Industrial Regions in India
(***Source:*** https:// www.patnauniversity. ac.in/ econtent/ social_ sciences/ geography/ MAG eog14.pdf)

Table 5.1 Data of India Industries

Industries	Total Numbers
Mining	1,531
Chemicals and Petrochemicals	12,168
Cottage (SSI)	128.44 Lakh
Defence Products	50 Labs 4 Defence Shipyards 12 Defence PSU
Fertilizers	128
Food Processing	37,175
Heavy Industries	
Manufacturing	2,42,395
Oil and Natural Gas	23 Refineries
Pharmaceuticals	10,500
Textiles	3400
Automobiles	14,000

2.4 About Adaptive Reuse

Adaptive reuse refers to the process of reusing an existing building for a purpose other than which it was originally built or designed for. It is also known as recycling and conversion. Adaptive reuse is an effective strategy for optimizing the operational and commercial performance of built assets. Adaptive reuse refers to the process of reusing an existing building for a purpose other than which it was originally built or designed for [3]. It is also known as recycling and conversion. Adaptive reuse is an effective strategy for optimizing the operational and commercial performance of built assets. Refer figure 5.3.

Figure 5.3 Brewing Company Brewing Company
(***Source:*** Modearchitects https://modearchitects.in/)

2.5 Importance of Industrial Adaptive Reuse

- **Maintains Cultural Heritage**: In communities with historic architecture, adaptive reuse is a form of historic preservation. It restores culturally significant sites that would otherwise be left to decay or demolished to make room for new buildings or parking lots.
- **Slows Urban Sprawl**: When builders search for new construction sites, they must often choose land further outside of a City Centre since the land within a city is usually claimed by old buildings or more expensive real estate. This fuels the process of "urban sprawl," a term for the unrestricted expansion of urban areas, contributing to air pollution and other environmental impacts, dangerous traffic patterns, higher infrastructure costs, and social isolation. Adaptive reuse offers a counter to urban sprawl.
- **Creates a New Community Beacon**: Adaptive reuse architecture is functional and often incredibly beautiful.

2.6 Advantages and Disadvantages of Adaptive Reuse

Refer table 5.2 for advantages and disadvantages of adaptive reuse.

Table 5.2 Advantages and Disadvantages of Adaptive Reuse

Advantages	Disadvantages
Existing inventory of well-built structures	Potentially high cost of development due to governmental processes such as permitting, planning and historic permissions.
Access to financing incentives	Potentially high construction cost due to common environmental issues

Potentially low acquisition cost	Higher design cost to address change-of-use, update infrastructure such as outdated HVAC and electrical systems
Proximity to large population centers	Existing building design layout and site constraints
Environmental benefits, such as reduced waste from demolition of old structures and reduced energy from generating new materials	Historic preservations designation can limit façade or exterior alterations
Adaptive reuse helps in reducing Urban Sprawl and thus solves the problem of Land Exhaustion	

2.7 Elements of Adaptive Reuse

Adaptive Reuse elements are very crucial in determining the number of alterations to be done in a building for its reuse. Industrial buildings need high number of alterations as its use is changed. An industrial building is always converted into a different use because of environmental issues. Converting a building needs design elements which is to be fused within the structure [4].

Elements of Adaptive Reuse which are most commonly followed are following:

1. Façade
2. Structural Constraints
3. Materials
4. A sense of Past

2.7.1 Façade

Preserving a society society's cultural and architectural heritage while balancing city growth is a difficult task. Many older buildings feature beautiful and historical designs, but require heavy changes to the actual building structure. Techniques such as architectural facadism—preserving the façade of a building while constructing a new internal structure behind it—offer an opportunity to compromise and preserve through adaptive reuse. Refer figure 5.4.

Figure 5.4 Caixa Forum
(***Source:*** architizer) https://architizer.com/blog/inspiration/collections/fill-in/

2.7.2 Structural Constraints

Before starting an adaptive reuse project and even considering refurbishment, it is important that the condition of the existing building is thoroughly assessed. A condition assessment primarily inspects a building's structural integrity. roofing, masonry, plaster, wood-work, tiling and the mechanical, electrical and plumbing systems. The in-depth inspection of buildings can be

expensive. Nevertheless, building condition assessment is critical to the success of an adaptive reuse project and must not be avoided at any cost because this expense is insignificant relative to the injury or loss of life that a building failure might cause.

2.7.3 Materials

Building materials are generally procured from the Earth's strata or are end products of processed natural components. These resources are limited. Irresponsible extraction of natural compounds for building material manufacture can deplete these natural compounds from the earth. Moreover, extraction can cause harm to the natural habitat and biodiversity of the region where materials are extracted. Therefore, a project that uses minimum new building material and uses more of recycled materials is a more sustainable and responsible choice for a building material. Refer figure 5.5 for major materials which are occupied after abandonment of Industrial Buildings are following:

- Steel
- Concrete
- Wood
- Stone
- Brick

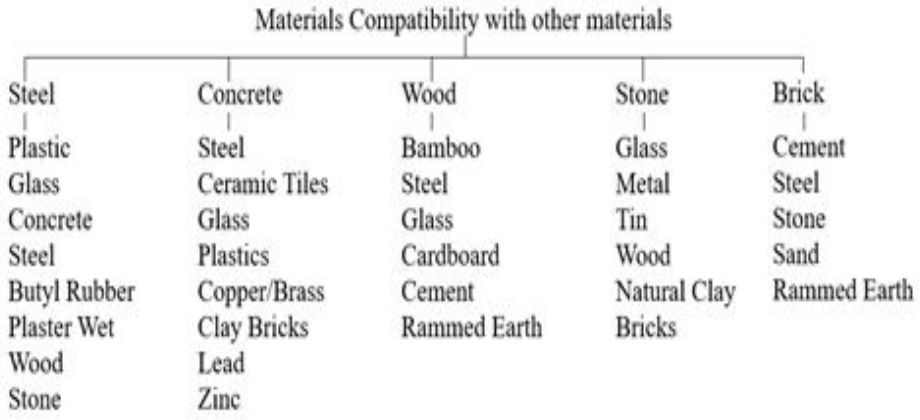


Figure 5.5 Material Compatibility with other materials

2.7.4 A Sense of Past

Architecture is an expression appropriate to its time, and adaptive reuse is a tool that can be utilized in the exploration of how to add to the existing fabric of a structure in order to continue the story of the building while still speaking to time and tradition.
A sense of past can be implemented in the hearts of people by taking following considerations:

- Having less alteration
- Keeping the fabric of the building secure
- Not extremely changing the use of the previous structure.
- Keeping the materials same.
- Implementing various design elements of the previous building in the new Adaptively Reused structure.

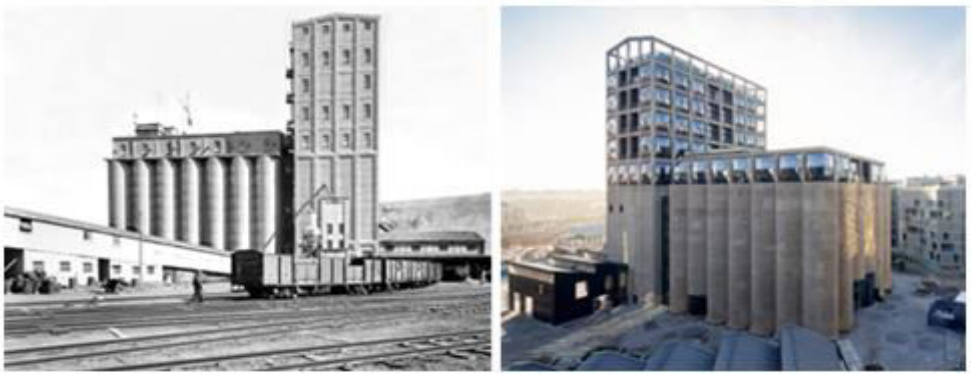


Figure 5.6 Zeitz Museum
(***Source:*** RTF https://www.dezeen.com/2017/09/15/thomas-heatherwick-zeitz-mocaa-cape-town-art-museum-south-africa/)

2.8 Impact of Adaptive Reuse on City Development

2.8.1 Controls Urban Sprawl

Urban Sprawl is characterized as "the spreading of metropolitan improvements on lacking area almost a city". Urban Sprawl has been depicted as the unhindered development in numerous metropolitan areas of lodging, business improvement, and streets over huge spreads of land, with little worry for urban planning [5].

Urban sprawl refers to the expansion of poorly planned, low-density, auto-dependent development, which spreads out over large amounts of land, putting long distances between homes, stores, and work and creating a high segregation between residential and commercial uses with harmful impacts on the people living in these areas and the ecosystems and wildlife that have been displaced.

2.9 Theories of Adaptive Reuse

2.9.1 Typological Approach of Different Buildings as Shown in Table 5.3

Table 5.3 Classification of Building Typologies

Building Type	Typologies
Industrial Buildings	Factory Warehouse Barn Granary Mills Mining Site
Religious Buildings	Church and Chapel Convent Bougienage Presbytery
Semi Public Buildings	City Hall Museum School Hospital Post office Library Hotel and Hostel

Residential Buildings	Castle Country house Farm Town House
Military Buildings	Fortress Barrack Gate
Commercial Buildings	Craft Shop Departmental Store Bank Market

2.9.2 Technical Approach in Adaptive Reuse

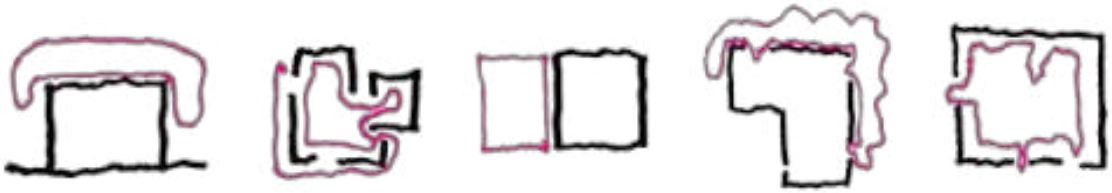
Table 5.4 Technical issues on Adaptive Reuse

Technical Types	Upgrading
Loadbearing Structures	Frames Floors Walls Roofs Heavy Lifting
Building Envelope	Internal Surface Introduction of new Floors Façade Accessibility and Circulation
Comfort, Safety, and Energy Efficiency	Fire Resistance Thermal Performance Acoustic Performance Preventing moisture and Dampness Indoor Air Quality

2.9.3 Strategic Approach

The Strategic Approach concentrates on the processes and strategies used for adapting important structures.

- Building within
- Building over
- Building around
- Building alongside
- Recycling materials
- Adapting to a new function



Wrap **Weaving** **Juxtaposition** **Parasite** **Insertion**

3. CASE STUDY

This section studies various cases of Industrial Structures which are Adaptively Reused and will be helpful in understanding that how, Strategic use of site-sensitive design for Industrial structures can contribute to physical life improvements, impact social behavior and contribute to lifestyle enhancements within the community. It discusses about how, Adaptive Reuse has a spirit of Sustainability, Conservation and Minimal Transformation, making it best fit for the future low availability of resources in the future. (Hypothesis)

Case studies will be helpful in determining and carrying out various design elements which can be used in different type of Industrial Structures.

- Alembic Industrial Heritage Development, Vadodara
- Google Headquarters, L.A
- Imagine Studios at the Trees, Vikhroli, Mumbai
- The Design Village, Noida, U.P

3.1 Alembic Industrial Heritage Development, Vadodara

The first-ever Alembic industrial building in Vadodara has seen multiple surgical interventions. Similar to many old factory buildings, the building got altered over time due to change in the original purpose of the facility. The space within is meant to serve the Alembic Museum, art studios, display and exhibition space with ancillary spaces for a library, AV room, and a café i.e. Refer figure 5.7.

Figure 5.7 Alembic Industrial Heritage Development, Vadodara
(***Source:*** archdaily https://www.archdaily.com/923851/alembic-industrial-heritage-and-re-development-karan-grover-and-associates)

Architects	Karan Grover and Associates
Location	Vadodara, Gujarat, India
Built in	March 2017-December2018
Client	Alembic Ltd.
Area	1,200 sqm
Structural Consultant	ADCE Structure Engineer

Changes after Adaptive Reuse

Table 5.5 Changes after adaptive reuse

Earlier	Now
Function: The function of the Industrial Structure varied time to time, when this Alembic industry started, it was used for the Manufacturing of penicillin, but before it got abandoned, it was used for the manufacturing of Alcohol.	**Function:** Now the Industrial Structure is converted into an Industrial Heritage Development building, which consists of Alembic Museum, art studios, display and exhibition space with ancillary spaces for a library, AV room, and a café.
Site Plan: The site plan of the industry was 12,520 Sqm. /3.09 Acre. There were no distilleries earlier in the site plan. These were added due to the manufacturing of alcohol.	**Site Plan:** The site plan increased from 12,520 Sqm/3.09 Acre to 14,472 Sqm. /3.58 Acre. In the new site plan, basketball court and skating ring is added.
Architecture Style: The style of architecture adopted by the Britishers in India was Indo-Saracenic, thus the industry was designed in an Indo-Saracenic way. The design elements which were present in the structure were: 1. Brick walls 2. Purlins and Rafters 3. Riveted Trusses 4. Arched Windows and Doors 5. White plaster 6. Terracotta tiles 7. Large span truss structures, etc.	**Architecture Style:** The style of architecture is preserved now for a feeling of sense of past for the users. Only servicing of the structure is done and rest of the structure is taken as it is.Design elements which were retained are: 1. White plater on Brick walls are sandblasted or removed from waterjet technique, from the areas where the condition of them is worse. 2. Strengthening of trusses. 3. New Mangalore tiles were used. 4. Arched windows & doors were serviced. 5. Purlins and Rafters were kept exposed to express the quality of structure that once it was.

3.2 Google Headquarters, L.A

Built by Howard Hughes in 1943 for the construction of the Hercules IV airplane the historic hangar now comprises office, meeting, food service and event spaces, and employee amenity spaces. The project included extensive restoration of the original wood frame, and the new architecture is set within the vast, open volumes of the hangar on either side of its fully restored central spine.

Figure 5.8 Inside of Google Headquarters, L.A
(***Source:*** archdaily https://www.archdaily.com/905622/zgf-reveals-googles-new-la-office-in-historic-california-hangar)

Architects	ZGF Architects
Location	Playa Vista, L.A, U. S
Built in	June 2016-February 2018
Client	Google
Area	41,806 sqm
Structural Consultant	GPA Consulting

Changes after Adaptive Reuse

Table 5.6 Changes after adaptive reuse

Earlier	Now
Function: The function of the Industrial Structure varied time to time, when this Hangar was constructed, it was used for the construction of Spruce Goose, but before it got abandoned, it was used for the transportation of Cargo's.	**Function:** Now the Industrial Structure is converted into a Google Headquarters building, which consists of Office Space, Kitchens, Art Rooms, Display Centres, Recording Studios, Meeting Rooms, etc.
Site Plan: The site plan of the industry was 1,08,724 Sqm. /26.87 Acre. There was a huge land for the Airplanes to move, thus the area of the hangar at that time was massive.	**Site Plan:** The site plan decreased from 1,08,724 Sqm/26.87 Acre to 41,806 Sqm. /14 Acre. In the new site plan, parking is provided for the cars.
Architecture Style: The style of architecture adopted by the Americans in L.A for the construction of Hangars was Classic Architecture, thus the Hangers was designed in a Classical way, that is with the use of woods and steel. The design elements which were present in the structure	**Architecture Style:** The style of architecture is preserved now for a feeling of sense of past for the users. Only servicing of the structure is done and rest of the structure is taken as it is.Design elements which were retained are: 1. Wooden purlin and rafters were retained with a little service on them 2. Strengthening of trusses

were: 1. Wooden Planks 2. Wooden Purlins and Rafters 3. Glulam Trusses 4. Large Span Windows 5. Massive Doors 6. Wooden Girt 7. Large span truss structures, etc.	3. Large span windows were kept as it was 4. Massive doors were serviced. 5. Purlins and Rafters were kept exposed to express the quality of structure that once it was

3.3 Imagine Studios at the Trees, Vikhroli, Mumbai

An Adaptive re-use project in Mumbai, the imagine studios weaves nature, heritage, and urbanism through a compelling narrative of evolving contexts. The erstwhile industrial site was transformed into an experiential journey consisting of a Studio, Workshop, Café, Legacy Park, Urban Farm, Open Air Theatre and Market Plaza to demonstrate the underlying principles of 'Live, Learn, Work, Play' in a mixed-use development.

Figure 5.9 Imagine Studios at the Trees
(***Source:*** studiolotus https://studiolotus.in/showcase/imagine-studio-at-the-trees/144)

Architects	Studio Lotus
Location	Vikhroli, Mumbai, India
Built in	February 2014-March 2015
Client	Godrej
Area	1,000 sqm
Structural Consultant	Sterling Engineering

Table 5.7 Changes after Adaptive reuse

Earlier	Now
Function: The function of the Industrial Structure varied time to time, when this Power Plant was constructed, it was used for the generation of power from steam and boilers, but before it got abandoned, it was used for a Co power generation setup.	**Function:** Now the Industrial Structure is converted into a Multifunctional building, which consists of Office Space, Cafes, Art Rooms, Landscaping, Workshops, Display Area, etc.
Site Plan: The site plan of the industry was 5,000 Sqm. /1.23 Acre. There was a huge land for the Cogeneration Power Plant to build.	**Site Plan:** The site plan decreased from 5,000 Sqm/1.23 Acre to 1,000 Sqm. /0.24 Acre. In the new site plan, the area is given to Taj Hotel.

Architecture Style: The style of architecture adopted for the construction of Power Plant was Classic Architecture, thus the Power Plant was designed in a Classical way, that is with the use of brass and steel. The design elements which were present in the structure were: 1. Steel Planks 2. Steel Purlins and Rafters 3. Steel Trusses 4. North Light Truss 5. Massive Doors 6. Steel Girt 7. Large span truss structures, etc. 8. Corten Steel Sheets 9. Silos and Boilers	**Architecture Style:** The style of architecture is preserved now for a feeling of sense of past for the users. Only servicing of the structure is done and rest of the structure is taken as it is. Design elements which were retained are: 1. Steel purlin and rafters were retained with a little service on them. 2. Strengthening of trusses. 3. Corten Steel Sheets were used again 4. Silos were used as Landscape element. 5. Purlins and Rafters were kept exposed to express the quality of structure that once it was. Steel trusses show the legacy of material Godrej used over time.

3.4 The Design Village, Noida

The whole work area is imagined as a dynamic and dynamic space, blended with particular interventions, novel, out-of-the container thoughts to motivate innovativeness among the understudies. The plan of the grounds is Driven by the educational vision of TDV-'Life through Design' that depends on the learning venture attempted by the understudy that empowers self-awareness while making/making/having an effect - on the individual, the general public and the climate overall. Refer figure 5.9.

Figure 5.10 The Design Village, Noida
(***Source*****:** Archplus Design https://www.architectureplusdesign.in/)

Architects	Studio Archohm
Location	Noida, U.P, India
Built in	May 2017-July 2017
Client	The Design Village
Area	2,150 sqm
Structural Consultant	Roark Consulting

Changes after Adaptive Reuse

Table 5.8 Changes after adaptive reuse

Earlier	Now
Function: The function of the Kattha factory didn't varied time to time, when this Factory was constructed, it was used for the manufacturing of Kattha, but due to environmental issues, government decided to ban this factory for the betterment of the neighboring industries and settlements.	**Function:** Now the Industrial Structure is converted into an Institutional building, which consists of Studio Space, Cafe, Art Rooms, Workshops, Display Area, faculty Rooms, Library, Computer Lab, Recreational Spaces etc.
Site Plan: The site plan of the industry was 6,450 Sqm. /1.59 Acre. There was a huge land for the Kattha factory to build.	**Site Plan:** The site plan decreased from 6,450 Sqm/1.59 Acre to 2,150 Sqm. /0.53 Acre. The site is divided into 2 industrial units.
Architecture Style: The style of architecture adopted for the construction of Kattha Factory was mix of Classical and Modern Architecture, thus the manufacturing factory was designed in a Classical way, that is with the use of Steel and Brick. The design elements which were present in the structure were: 1. Steel Planks 2. Steel Purlins and Rafters 3. Steel Trusses 4. Brick Walls 5. Mezzanine Floors 6. Large truss structures 7. Steel Sheets 8. Boilers and Machines	**Architecture Style:** The style of architecture is preserved now for a feeling of sense of past for the users. Only servicing of the structure is done and rest of the structure is taken as it is.Design elements which were retained are: 1. Steel Mezzanine floors were retained with a little service on them, 2. Strengthening of trusses. 3. Steel Sheets were used again. 4. Pump room is used as Faculty room. 5. Various areas which were used for a purpose of Kattha are now reused as different rooms like Computer Lab, Faculty room, Deans Room, etc.

4. CONCLUSION

This research strives to offer possible strategies for the successful adaptive reuse of Industrial buildings with causing minimum interferences in the existing forms, designs and interior elements. It demonstrates that it is not only important to retain and restore but also to adapt them so as to give them new uses that are similar to their original intents. Adaptations for contemporary use have resulted in new forms based on old forms but adapted for contemporary use. The research also focuses on preserving the spirit of existing form and space. This process looks at long-term feasibility for a neighborhood, specifically, it proposes the transformation of uses for different building typologies.

The life span of the building is somewhat similar to a human, namely the "cradle to grave" period. Anything in the designers' power to prolong a buildings life span must be carried out. This is because the building is already built, it is well connected, and it failed predominantly due to a change in the political, economic or cultural context. If the building had become a subject of obsolescence due its structural failure, then the investment in its future is questionable.

REFERENCES

1. P. F. CHERCHI, "Adaptive Reuse of Abandoned Monumental Buildings as a Strategy for Urban Liveability," Institutional Research Information System, 2015.
2. B. S. ,. A. K. ,. V. M. Nataša Petković-Grozdanovića, "The Possibilities for Conversion and Adaptive Reuse of Industrial Facilities into Residential Dwellings," Procedia Engineering, pp. 1836-1844, 2016.
3. I. Vardopoulos, "Critical sustainable development factors in the adaptive reuse of urban industrial buildings. A fuzzy DEMATEL approach," Sustainable Cities and Society, pp. 1-12, 2019.
4. B. P. a. K. V. Cleempoel, "Adaptive Reuse as a Strategy towards Conservation of Cultural Heritage: a Literature Review," Conference: Proceedings Structural Studies, Repairs and Maintenance of Heritage Architecture XII, pp. 1-10, 2011.
5. Z. Karakayaci, "The Concept of Urban Sprawl and Its Causes," Journal of International Social Research, pp. 815-818, 2016.

Chapter 6

INTERIOR LANDSCAPING AS TOOL FOR A SUSTAINABLE AIRPORT DESIGN

Swati Punyal[*] and Naaz Warsi[2]
[1]Assistant Professor, Delhi Technical Campus, Greater Noida, India
[2]Student, Delhi Technical Campus, Greater Noida, India

ABSTRACT

In an increasingly urbanized world, mankind is slowly losing contact with the natural environment. Studies have shown that the introduction of plant material into the built environment has several benefits, both measurable and non-measurable. Measurable benefits include glare reduction, acoustical control, defining space, and an improvement in air quality. Non-measurable benefits include softening the hard lines of architecture, a feeling of well-being, and a stress reduction. This has become especially important in an airport, and both designers and airport administrators are seeing the value of increasing the use of indoor landscapes to enhance the guest experience and create branding opportunities.

Interior landscaping at airports is taking on a more important role to achieve those goals. In the creation of these landscapes, the designer must consider several aspects to ensure success. These are light, water, drainage, temperature, HVAC systems, air pollution, relative humidity, structural engineering, access, and maintenance. This paper aims establish the factors that impact CO_2 emission & new sustainable techniques of airport design w.r.t interior landscaping.

Keywords: Green airport, Terminal planning, carbon footprint, interior landscaping, Energy efficiency.

1. INTRODUCTION

The impact of greenhouse gases is currently being noticed in the ecosystem, which is a warning sign of future grave consequences. This has spurred a desire to do research to the development of ecologically beneficial and long-lasting technologies. Measures have been used to limit all possible sources of pollution. It is important to note that "Aviation" is a major source of air pollution that has eluded all radar systems and continues to be unregulated [1]. Many architects are seeking to design environmentally friendly airports, while aviation manufacturers are working to produce more environmentally friendly modes of transportation [2].

The design features for the Terminal building, which is the interface between land and air transit, as well as airport terminals as city icons. The architecture of the Terminal building necessitates a variety of analyses and interpretations. Airports serve as symbolic and initial impressions of a city as magnificent gateways. As a result, both the form and function of Terminal buildings are equally important in terms of planning and design. Cities compete for world-class airports, whether domestic or international, because they represent as much a city's pride as any other monument or landmark, catering to visitors from all over the world [3]. Airports are typically designed for a longer life cycle, to be able to expand in the future. The land-side and the air-side of a terminal are opposite one another. While passenger pleasure and safety are paramount, aircraft operations necessitate meticulous planning and supervision on the ground. They are enormous structures with a variety of architectural and technical design details. Apart from the core objectives of passenger demands, airline operating needs, and airport management-safety and security, there is also a community goal, which involves a facility for citizens; the airport building itself is an aesthetic and important element of the city. The expansion of air travel in Indian cities is unparalleled, and passengers demand a pleasant airport experience. The current topic in India is 'Green Airports,' which are designed and conceptualized with a social and environmental approach [4].

This paper aims establish the factors that impact CO_2 emission & new sustainable techniques of airport design w.r.t interior landscaping. The main objectives of this paper are to identify the problems like -carbon emission, Greenhouse effect, construction waste, and increase in temperature in terminal design and operation stage, and also to establish design consideration for interior landscaping in the airport. The scope of the study is confined to identifying CO_2 emissions in the airport and creating a space that has a minimal harmful impact on nature, reduction of the environmental impact on nature using interior landscaping, for example, to reduce CO_2. Also, identifying the various choices accessible during the design process to reduce energy use.

2. TERMINAL PLANNING AND DESIGN PROCESS

This section highlights the literature study done to understand the basics of Airport 2.1

2.1 What is the Terminal Complex

Airport terminals serve a diverse spectrum of users, including airlines, air travelers, well-wishers, and other airport tenants. Airport management, government regulatory agencies, air carriers, concessionaires, and other airport tenants are also among those who tend to use airport terminals. First and foremost, terminal facilities must guarantee a good level of service to their customers, but ensuring maneuverability and access to the ground has a significant impact on the building's architecture and planning. The terminal complex acts as a center for planes, passengers, and a variety of land-based transportation options. As a result, the terminal complex is divided into three fundamental components (refer figure 6.1): airside, terminal, and landside.

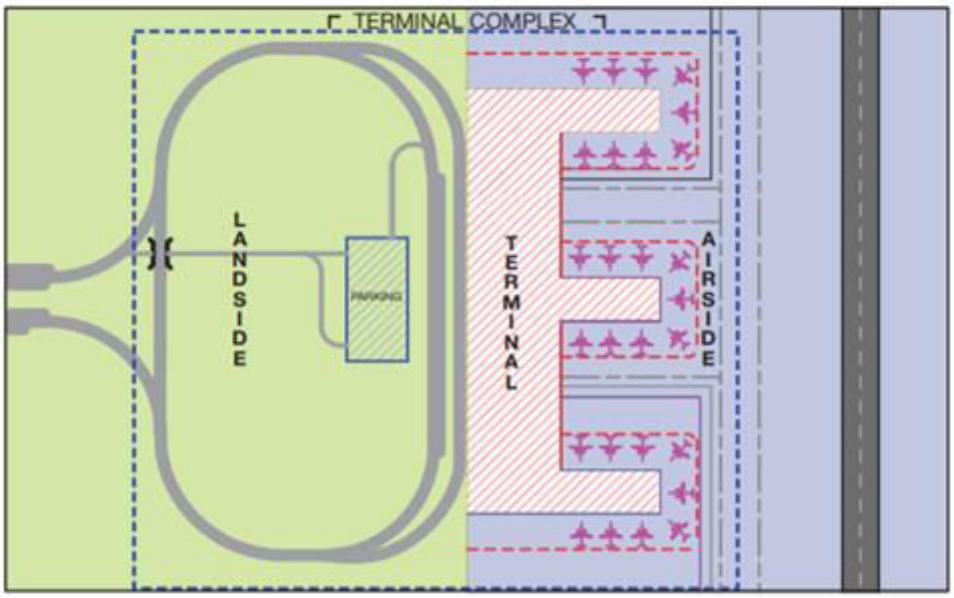


Figure 6.1 Terminal complex airport design.
(***Source:*** Google images)

2.1.2 Airside Terminal Facilities

For the majority of new terminal planning and design projects, it is necessary to build solutions based on the airside component from the start. This includes assessing gate requirements, identifying aircraft parking locations, and supporting taxi lanes that increase the airfield's overall efficiency before designing the internal layout of the terminal building and the landside curb and terminal roadway systems. The ability of aircraft to park at the terminal and navigate safely around the airfield using FAA Advisory Circulars' taxi lane/ taxiway regulations is critical, and the overall efficiency of passenger processing through the terminal is heavily influenced by airfield operations. The airside's large spatial requirements and rigid

requirements. Rather than the passenger processing requirements within the terminal building or its associated landside components, the physical geometry of the terminal complex is typically driven by the airside's large spatial requirements and fixed requirements for aircraft wingtip separations and maneuvering clearances. The physical layout of the terminal complex is frequently dictated by aircraft wingtip separations and maneuvering clearances rather than passenger processing needs within the terminal structure or associated landside components.

2.1.4 Terminal Building Facilities

Because of the ever-changing nature of the airport and aviation industries, today's airport terminal buildings must be designed and constructed in such a way that they can be easily modified in the future, while also responding to changes in demand and/or the needs of passengers, airlines, and aircraft.

To help the airport and its operators achieve these aims, the planning itself must be flexible, balanced, and visionary. The key to effective terminal planning now and in the future is to maintain a broad and balanced view of the planning process. The most essential functional and operational drivers, such as commercial concerns that affect the airport and its operators, as well as the surrounding community, should be considered during the terminal development process.

2.1.5 Landside Terminal Facilities

In some planning scenarios, landside components may be the driving force behind the most appropriate terminal complex solution. Because the efficacy, or lack thereof, of landside terminal amenities can have a significant impact on air travelers' perceptions of the airport's overall efficiency and user-friendliness, it must be properly planned.

The terminal landside system connects the airport to local ground transportation. Passenger connectivity by road and, where possible, rail from various landside access points to the terminal should be as seamless and convenient as possible, with the least amount of pedestrian level changes as possible. Landside components may be the driving force behind the most appropriate terminal complex solution in various design circumstances.

The airport's terminal landside system links it to local ground transit. From multiple landside access points to the terminal, passenger connectivity by road and, when practicable, rail should be as seamless and convenient as possible, with the least amount of pedestrian level changes as possible.

2.1.6 Airports Planning

The term 'airport' can apply to a variety of locations, including commercial airports, airfields (which may or may not have any accompanying structures), and heliports. They are either public (i.e., open to all air travelers) or private (i.e., not open to all air travelers) (e.g., air-freight terminals, corporation airports, aeroclubs, and air force bases). Kindly refer figure 6.2 for more details.

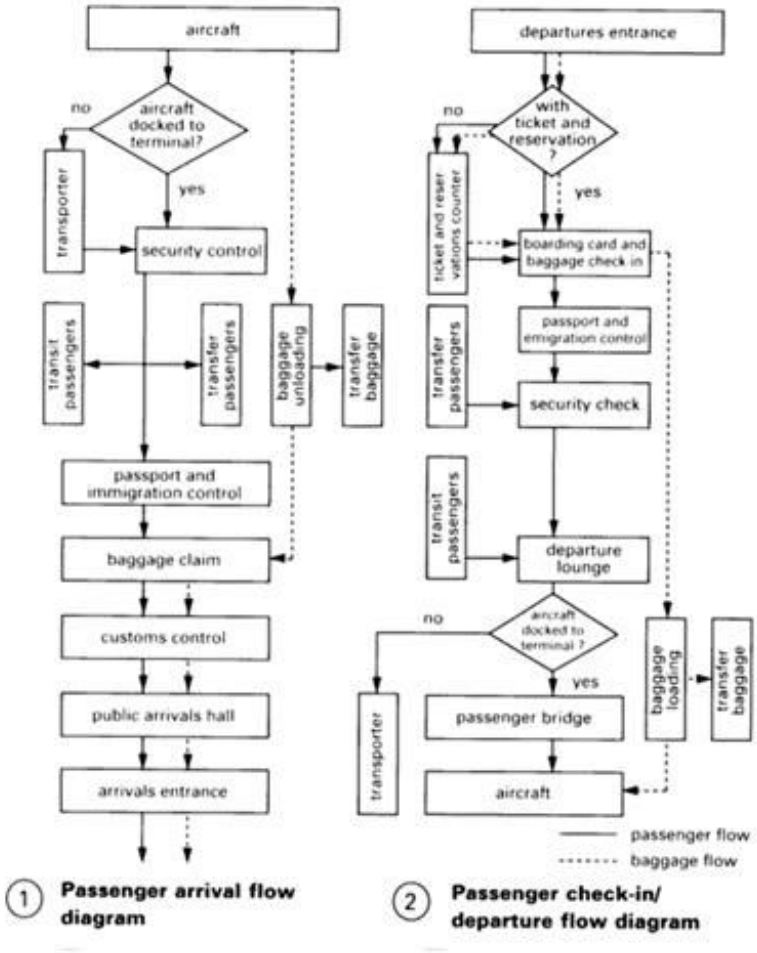


Figure 6.2 Flow chart of circulation.
(***Source:*** NBC https://www.bis.gov.in/standards/technical-department/national-building-code/)

2.1.7 Airport: Terminals

The following functional aspects define an airport's capacity:

- Take-off and landing runway system (number of aircraft movements per unit time);
- Taxiways and arrival/departure gates;
- Passenger terminal structures (possible movements of passengers, baggage, and air-freight per unit time).
- The capacity of the check-in system is determined by the following factors:
- The associated road and rail systems (including parking and road capacity);
- Passenger/baggage check-in clearance (number of counters and conveyor/transport system capacity); and passport control, security checks, and pre-boarding inspections (size of waiting rooms, number of counters).
- The apron is the area that connects the runways to the terminal.

Because it includes taxiways, aircraft maneuvering/parking spaces, accompanying traffic zones, and roadways for service vehicles, as well as storage places for service vehicles and equipment, it should be built in tandem with the terminal. Kindly refer figure 6.3 for more details.

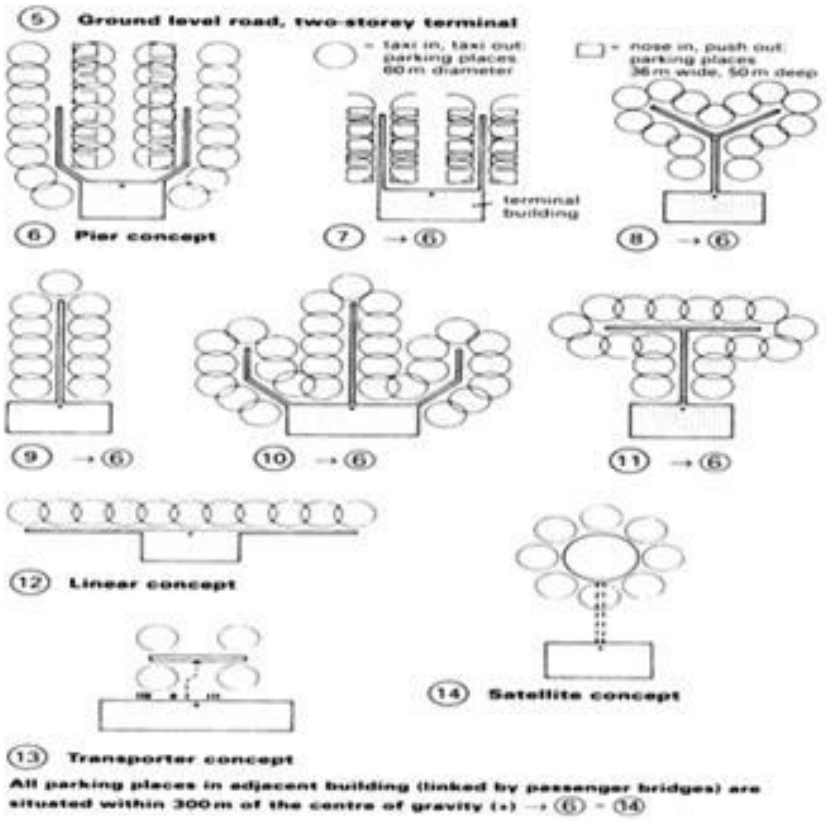


Figure 6.3 Different types of typologies.
(***Source:*** NBC https://www.bis.gov.in/standards/technical-department/national-building-code/)

2.2 Carbon Footprint

2.2.1 What is a Carbon Footprint?

Increasing the amount of greenhouse gases in the atmosphere causes environmental disruption, leading to severe global warming and its consequences. Measurements of the greenhouse gas intensity of various products, bodies, and processes are made all over the world and expressed as carbon footprints, following the principle that only what can be measured can be managed. Carbon footprint assessment methods are evolving, but they are quickly becoming a valuable tool for reducing greenhouse gas emissions. Although the notion of carbon foot printing has permeated and is being monetized in all parts of life and the economy, there is little agreement in how carbon footprints are defined and computed among studies. There are differences in the selection of gases to be included in footprint estimates, as well as the sequence in which they should be included. The most common resources used in footprint calculations are greenhouse gas accounting standards, while footprint verification is not required.

2.2.2 Emissions of GHG from the Energy Industry

The two main energy-related emissions examined in this industry are emissions from power generation and fugitive emissions. Emissions from the use of fossil fuels and electricity in different sectors, such as residential and industrial, are displayed individually. Kindly refer figure 6.4 for more details.

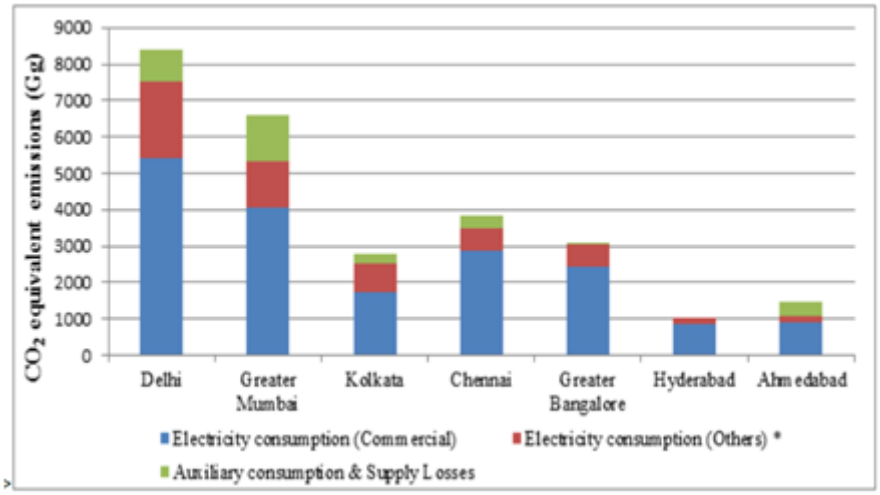


Figure 6.4 Electricity consumption. (Source: Author)

2.2.3 The Domestic Sector's GHG Emissions

When city-level investigations are carried out, the home sector is found to be a major source of emissions. The two main sources are electricity for lighting and other household devices, as well as fuel for cooking. The greenhouse gases released by household electricity consumption and fuel consumption are taken into account in this study. The main fuels used in this study are LPG, Piped Natural Gas (PNG), and kerosene, according to the available data. The graph below depicts total CO_2 equivalent emissions from the household sector in major cities.

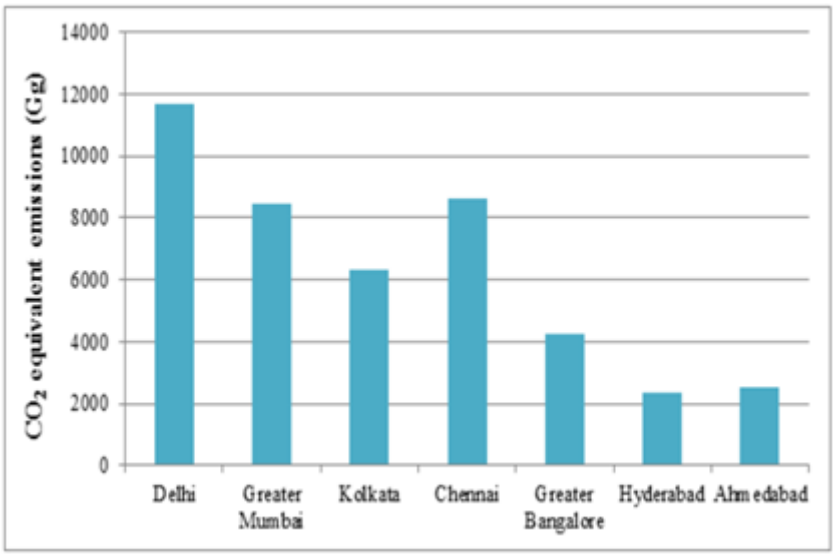


Figure 6.5 Carbon emission by domestic sector.
(***Source:*** Author)

2.2.4 The Transportation Sector's GHG Emissions

The transportation industry is one of the greatest anthropogenic sources of greenhouse gases in major cities. Emissions are computed for all vehicles registered inside the municipal limits, as well as CNG-fueled vehicles found in a few big cities. The emissions inventory includes port city navigational activities based on fuel usage. Delhi ranks #1 among other cities in terms of pollution due to its large number of autos. The total number of automobiles in Delhi exceeds the total number of vehicles in Mumbai, Chennai, and Kolkata combined, according to data from the Delhi Transport Department. Kindly refer figure 6.6 for more details.

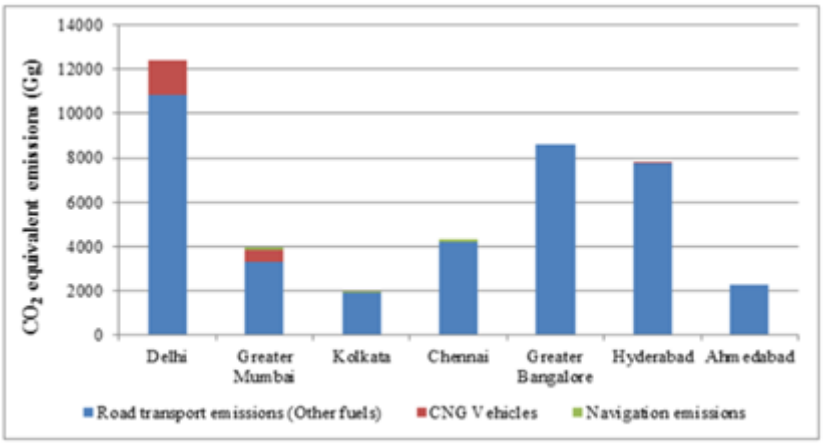


Figure 6.6 Carbon emission by transport sector.
(***Source:*** Author)

2.3 Carbon Emission by The Delhi Airport

India's total emissions are equivalent to the annual emissions of five coal plants. On average, 85 grams of CO_2 are emitted each passenger, per kilometer. Indira Gandhi International Airport in Delhi produces the most carbon emissions, ranking first in India. Kindly refer figure 6.7 for more details.

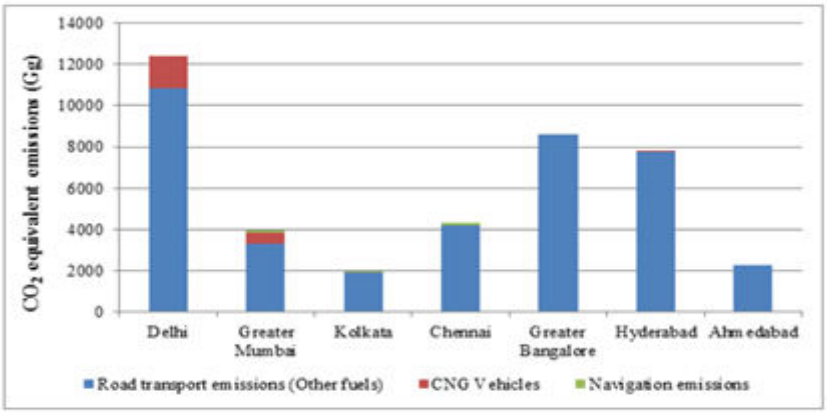


Figure 6.7 Indira Gandhi international airport, DELHI.
(***Source:*** Author)

Delhi airport releases 5.53 million tons of CO_2 annually.

•In figure 7, we can see that Delhi has the lowest carbon emissions in 2021 because due to Covid 19, planes are not operating and people are unable to go.

2.4 Major Concerns and Challenges

The use of non-sustainable energy sources in building design, construction, and operation is posing a serious threat to the building sector's long-term viability. The urbanization processes of huge use of land have also led to CO_2emission.

Despite the fact that fossil fuel energy is unsustainable, it accounts for a considerable amount of the energy used in building and operation. In the construction business, sustainable or renewable energy sources account for only 6% of total energy consumption, whereas fossil fuels account for 40% of worldwide greenhouse gas emissions. Despite the fact that several inventive approaches to lower buildings' CO_2 footprints, particularly in high-density metropolitan regions, have been proposed.

The use of a non-sustainable energy source has a direct environmental impact that is proportional to the amount consumed. During the construction of a structure, CO_2 is released both directly and indirectly. Direct CO_2 emissions are produced by burning natural gas, diesel, light fuel oil, and other oil-based commodities, whereas indirect CO_2 emissions are produced by using electricity.

Indirect CO_2 emissions account for 85% of total world CO_2 emissions, while direct emissions account for only 14%.

As per Climate and Energy Framework 2030, renewable energy should account for 27% of total energy consumption, and energy efficiency or productivity should increase by 27%. Finding long-term solutions to low productivity and efficiency, on the other hand, is tough.

To deal with the broader issues, one option is to categorize the construction and operation procedures. Construction includes the assembly of building materials, the creation of the structure and foundation, as well as the transportation and operation of machinery. The strategy includes the upkeep of both buildings and infrastructure. A detailed study and analysis of the processes of all stages of the building's life is required for the life cycle evaluation process. [5]

2.4.1 Strategies and Way Forward

Figure 6.8 Strategies to reduce CO_2.
(***Source*:** Google images)

For the past two decades, governments and politicians have been pushed to take action to cut CO_2 emissions in a variety of businesses. In response to worries about the building sector's contribution to globa CO_2l warming, this section examines a variety of CO_2 emission reduction measures. CO_2emissions of varying sizes can be reduced using these tactics [5].

2.4.2 Emission Sources in Airports

A. SCOPE 1: Emissions from airport operators

- Airport power plants, which provide electricity and heat/cooling
- Airport fleet vehicles, such as transfer buses and site machinery
- Building energy use, such as lights, HVAC, and machinery

B. SCOPE 2: AIRCRAFT EXEMPTIONS

- Emissions from aircraft engines during LTO, taxiing, and cruising
- Most ground support and ground handling equipment

Landside (off-site) ground access vehicles and trains as shown in figure 6.9

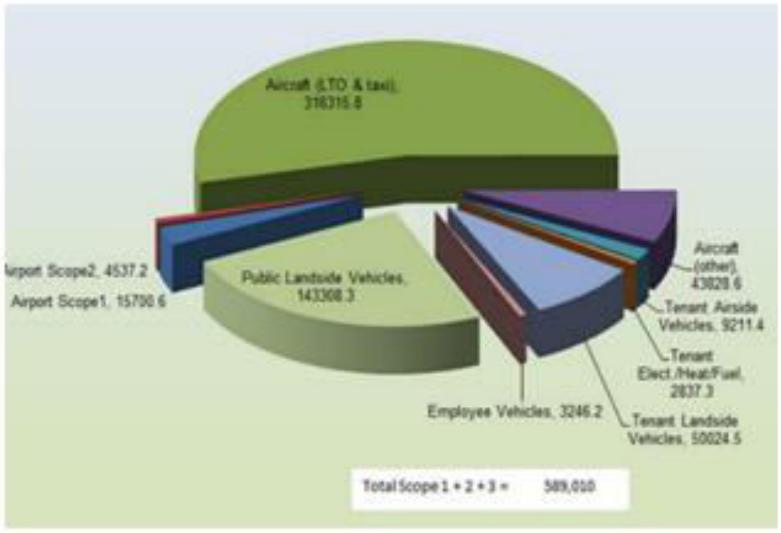


Figure 6.11 LEED rating system.
(***Source:*** UGBC https://www.usgbc.org/leed)

2.4.3 Energy Efficiency

Energy consumption has become a major worry in today's world. This is owing to the non-renewable nature of a major source of energy, particularly fossil fuels, as well as the pollution produced by this energy source. To mention a few consequences, burning fossil fuels depletes the ozone layer and increases carbon dioxide levels in the atmosphere. The need for renewable, non-polluting energy sources like solar and wind is increasing.

Airports are the cornerstone of the aviation industry. Airport terminal operation, maintenance, and amenities are a source of pride for the towns and countries in which they are located, and they help to boost tourism and the general image of the place. They are iconic structures that influence visitors' first impressions of a country. As a result, a large sum of money is spent to ensure that passengers have a nice experience at the airport. This typically necessitates dedicating a substantial amount of time and attention to ecosystems that improve the ambiance and user experience [6].

Many airports throughout the world have adopted environmentally friendly procedures and energy sources without compromising the customer experience. Some of these techniques have been shown to reduce individual airports' environmental effect. People's concerns about energy, or the lack thereof, have grown in recent years. Energy-efficient technology have received a large amount of research and investment.

A large quantity of energy is consumed by an airport, which includes both airside and landside uses. The regions that tend to the needs of aircraft, such as runways, hangars, and control towers, are referred to as airside. Landside refers to the locations that attend to the passenger's needs while guaranteeing a smooth and safe transit, such as terminal buildings and parking spaces. The terminal building accounts for the majority of energy use at an airport. The terminal building at the Santander airport in Spain consumes more than 75 percent of total energy. Other airports may follow a similar, if not identical, pattern.

This energy is used for lighting, air conditioning, and luggage handling systems, among other things. Fortunately, terminal buildings offer a wide range of options for long-term operations. In airports throughout the world, everything from sustainable energy sources to efficient HVAC systems and sustainable lighting has been implemented. The energy usage of the facilities at Santander Airport is depicted in the graph below [6]. Refer figure 6.10

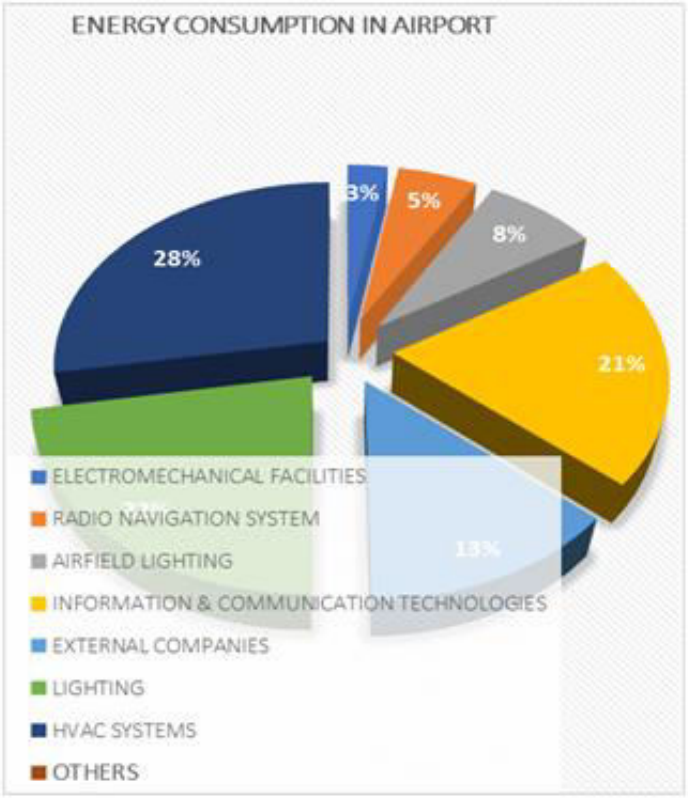


Figure 6.10 Energy consumption of airport.
(***Source:*** AAI https://www.aai.aero/en)

2.4.4 Green Building Concept

Throughout their lives, buildings have had a significant impact on the environment. Buildings require a variety of resources, including soil, trees, water, and numerous energy types. For example, water, the most important resource, is used continuously during the construction and operation of buildings. Similarly, some buildings, in conjunction with the utilization of resources, produce enormous volumes of garbage that can be recycled and reused. As a result, the task a green construction is to make the most efficient use of resources while also ensuring effective waste disposal at a reasonable cost.

For many years, the terms "going green" and "environmental sustainability" have been used to emphasize the need of sustainable construction approaches. According to official statistics, the structure continues to be a substantial energy consumer. This may be due to the construction industry's lack of interest in environmentally acceptable alternatives. The demand for ecologically friendly building materials has recently increased as a result of rising energy prices and growing environmental concerns. Authorities and government agencies created green building rating systems to reduce/optimize natural resource use and pollution. Buildings with those certifications are expected to use less energy, provide a better living environment, and boost the property's overall reputation. Around the world, there are an estimated 600 green rating systems in use.

Green building is defined by the Office of the Federal Environmental Executive as "the practice of:

- Improving the efficiency with which buildings and their sites use energy, water, and materials, and
- Reducing building impacts on human health and the environment, through better siting, design, construction, operation, maintenance, and removal throughout the entire life cycle."

A green building is one whose design and operation promotes the healthiest possible environment while also being the most efficient and cost-effective alternative.

2.4.5 Green Rating System of Building

A green building rating system is a mechanism for evaluating a structure's environmental performance over the course of its lifespan. It usually consists of a collection of guidelines that cover many areas of the design, construction, and operation of a green building. Each criterion defines verifiable performance targets and goals and includes a set of predetermined points. A list of some of the most effective international rating programs is provided below, along with an explanation.

LEED

LEED (Leadership in Energy and Environmental Design) was founded in 1998 in the United States. This is the world's most popular green building rating system. For grading the structures, the rating system is based on a set of environmental and building-related criteria.

On January 1, 2007, the Indian Green Building Council changed the LEED system and introduced the LEED India version.

The CII-Godrej GBC, ITC Green Centre Gurugram, and Wipro Gurugram, to name a few, are among the 650 LEED certified green buildings in India.

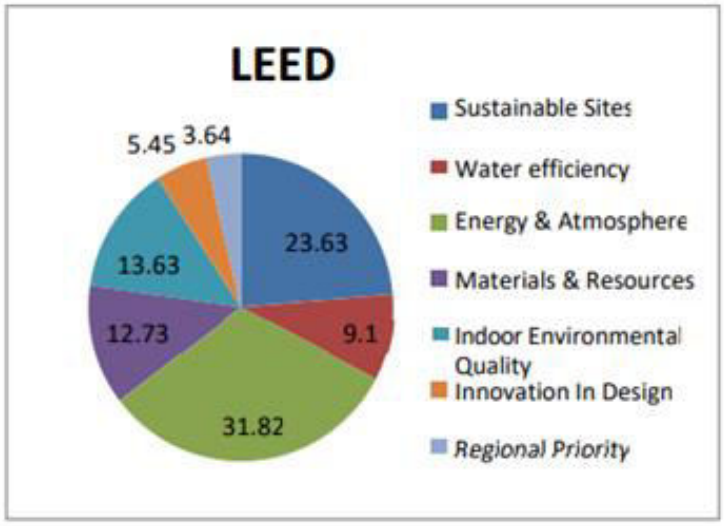


Figure 6.11 LEED rating system.
(***Source:*** UGBC https://www.usgbc.org/leed)

BREEAM

The Building Research Establishment's Environmental Assessment Method (BREEAM), which was developed in the United Kingdom in 1990, is one of the earliest building environmental assessment systems. The building types covered by BREEAM include offices, residences, industrial units, retail units, and schools. When a building is evaluated, each criterion is assigned

a point value, and the total score is calculated. The overall performance of the building is graded as 'Pass,' 'Good,' 'Very Good,' or 'Excellent,' based on the score. BREEAM provides a number of criteria/checklists for assessing Design and Procurement, as well as Building Management and Operations.

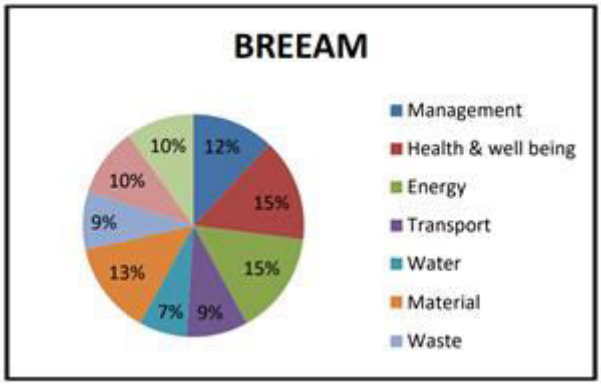


Figure 6.12 BREEM rating system.
(***Source:*** UGBC https://www.usgbc.org/leed)

GRIHA

The bulk of internationally recognized grading systems are peculiar to a country's construction industry. The Energy Resource Institute (TERI) in New Delhi took on the task of establishing a grading system to analyze a building's environmental performance in the context of India's different climate and construction practices with the purpose of boosting green building construction in India.

The rating system will evaluate the building's performance across its entire life cycle based on the Green Building practices utilized during construction, operation, and maintenance. The rating method developed by TERI is known as the Green Rating for Integrated Habitat Assessment (GRIHA).

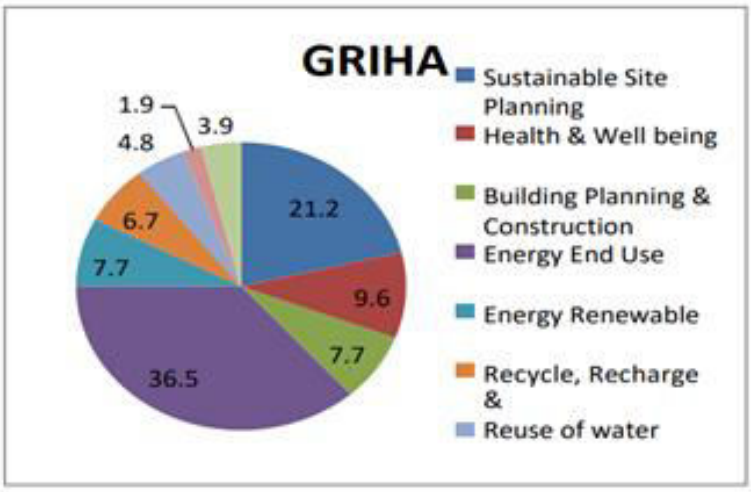


Figure 6.13 GRIHA rating system.
(***Source:*** GRIHA Official https://www.grihaindia.org/)

2.4.6 Solutions to Reduce CO_2 Emission in Airport

According to recent research by the online tool Airport Tracker, Delhi Airport's CO_2 emissions are much lower than those of other major global airports. Total flight emissions from Delhi Airport are 5.53 million tons of CO_2.

1. Use of green building concepts in construction and operation
2. Use of renewable energy with the establishment of a 7.84 MW solar power plant on the airside

- Delhi Airport also adopted a green taxiing gadget called the "Taxi Bot" that minimizes fuel consumption and emissions from airport operations.
- In an airport, use inside landscaping to assist reduce carbon emissions and improve indoor air quality.
- The following are some of the most important things to take to guarantee that power consumption is reduced:

1. Energy-efficient construction materials
2. Electronic and electromechanical systems
3. Lighting solutions that are energy efficient

2.5 Green Airport WRT To Interior Landscaping

The impact of greenhouse gases is currently being noticed in the ecosystem, which are warning signs of future grave consequences [7]. This has piqued my interest in conducting research aimed at developing long-term solutions. They are technologically advanced while also being environmentally friendly. All potential sources of contamination have been restricted through measures. It is important to note that "Aviation" is an important category. A source of air pollution that has slipped all radar systems and continues to operate unchecked. While the aviation sector is booming, many architects are seeking for more ecologically friendly ways to fly and are aiming to design environmentally friendly airports [8].

Green Airport's long-term goal is to create a hub for sustainable practices, including flight instruction, aviation and environmental education, recreational flying, eco-tourism, and scheduled passenger operations [9]. The airport's expansion is limited by noise pollution, environmental limitations, physical space needs, and the quality of life in and near the airport. Another stumbling block is that many airports have huge image problems in the community. The construction of a green airport will help to promote energy independence while also improving economic conditions. Sustainable investments are seen as required investments that help the airport generate value [10].

2.5.1 Design Considerations for Interior Platescapes in Airports

Mankind is gradually losing contact with the natural environment as the world becomes more urbanized. Plant material in the built environment has been found to provide numerous benefits, both quantifiable and non-measurable, according to studies. Glare reduction, noise management, spatial definition, and improved air quality are all measurable benefits. Softening the rigid lines of architecture, a sense of well-being, and a stress reduction are all non-measurable benefits. This is especially true in airports, where both designers and airport managers see the importance of expanding the use of interior landscapes to improve the visitor experience and offer branding opportunities.

Interior landscaping at airports is becoming more significant to attain those goals. To ensure the success of these settings, the designer must consider various factors. Light, water, drainage, temperature, HVAC systems, air pollution, relative humidity, structural engineering, access, and maintenance are some of these factors.

- **DAYLIGHT**

Light is required for all plants to survive; however different plants have different light requirements. The three components of lighting for plant maintenance must be considered:

intensity, duration, and quality. The landscape architect should collaborate with the lighting designer to ensure that the plants receive enough light to grow.

Except during plant rest time, minimum lighting intensities on the ground plane should never go below 50-foot candles. The illumination intensity for the appropriate plant material should be considered as part of the space design. This identifies the right plant materials for the space. The duration should be planned over seven days with a continuous 14-hour session. While there has been a lot of talk about plants being overworked if they aren't given a low light rest period, no definitive research has been done to back up this claim.

Interior landscapes should use artificial light either alone or in conjunction with natural daylight. It's vital to remember that any form of light can start photosynthesis within the plant, therefore the length of light is more significant than the intensity or hue of light. Because plants can most efficiently use light in the red and blue ranges, fluorescent lamps with primarily blue light outputs are recommended. LED bulbs are another wonderful option because they are energy-efficient and can be color-controlled. Because up lighting is only partially as effective as lighting the plant leaf tops, it should not be used as the only source of illumination. However, uplighting is useful for illuminating the plant's interior.

Daylight is generally recommended as a cost-effective and pleasant source of ambient lighting. If it is to be the dominant light source, it must be carefully developed and calculated. The actual light intensity falling on the plant material must also be considered when limiting skylights or vertical glass. Natural lighting is affected by factors such as latitude, season, sun altitude, weather, and cloud cover.

The majority of nursery plants are cultivated in strong light outdoors; therefore, the landscape architect should stipulate a four- to six-month acclimation period for plants before installation to ensure they are ready for the lower light circumstances. The plants will deteriorate if they are not properly acclimatized.

- **WATER**

Daylight is generally recommended as a cost-effective and pleasant source of ambient lighting. If it is to be the dominant light source, it must be carefully developed and calculated. The actual light intensity falling on the plant material must also be considered when limiting skylights or vertical glass. Natural lighting is affected by factors such as latitude, season, sun altitude, weather, and cloud cover.

The majority of nursery plants are cultivated in strong light outdoors; therefore, the landscape architect should stipulate a four- to six-month acclimation period for plants before installation to ensure they are ready for the lower light circumstances. The plants will deteriorate if they are not properly acclimatized.

- **DRAINAGE**

To avoid root rot and fungus growth, the soil should be light and well-drained. Drainage pipe should be installed at the bottom of pots and planters, leading to a vertical PVC pipe that runs to the top of the planting soil. The vertical pipe should be large enough to handle a shop-vac hose, allowing not only for the evacuation of excess water, but also for other foreign waste thrown into planters, such as coffee, drinks, and so on. The pots can be moved around with this arrangement to accommodate future upgrades. Drains in planters will need to be waterproofed and have the bottom slanted toward the drain to ensure proper drainage. The landscape architect and the MEP engineers will need to work together.

- **TEMPERATURE**

Temperatures between 70- and 75-degrees Fahrenheit during the day and 10 degrees lower at night are ideal for most indoor plants. Extreme heat or cold, as well as rapid temperature swings

of 30-40 degrees, can kill plants. Never allow the temperature to fall below 32 degrees Fahrenheit.

- **HEATING, VENTILATION, AND AIR CONDITIONING**

Carbon dioxide levels are usually high enough in most interiors that only standard ventilation is required to replenish the CO_2 used in photosynthesis and prevent air stagnation around the plant. In high-light situations, ventilation is also essential to avoid heat build-up around plants (the greenhouse effect) and possible foliar burn.

Unless the air is exceptionally cold, air-conditioned spaces are neither hazardous nor beneficial to plants. Plants should not be placed in the direct path of supply grille airflow. This is especially critical during the heating cycle, because direct blasts of hot air will not only dry out the plants much faster due to the lower humidity, but they may also burn the plant leaf.

- **AIR POLLUTION**

When working with interior plants, this is usually not a serious issue because there are air handling systems in place. However, the designer should use caution while choosing interior finishes and cleaning processes. Harsh cleaning agents used around the planters, such as ammonia or carbon tetrachloride, can harm the plants and turn the foliage black, which is a common symptom of gas-related issues. Plants can potentially be harmed by high quantities of varnish and paint off-gassing. Unburned gas (hydrocarbons) from heating units, high chlorine concentrations, such as in swimming pools, and even high cigar or cigarette smoke concentrations are all threats to plants. Most gas-related issues can be avoided with adequate ventilation and a proper exhaust system.

- **RELATIVE HUMIDITY**

The majority of interior plants are cultivated in 60 to 90 percent relative humidity, but they can readily withstand the conditions that humans thrive in. While some plant kinds may have problems under low heat cycle settings of 30 to 50 percent humidity in normal winter circumstances, the majority of problems appear when the reading drops below 30 percent humidity. Electric humidifiers and fountains can be utilized to alleviate these situations, which are normally unpleasant for people. The majority of indoor foliage plants should be able to grow if human occupants are happy.

- **STRUCTURAL**

Plant material can be set up in three different ways:

- Staying in their pots inside a planter, with structural foam and Spanish moss filling the spaces, or in a soil-filled planter area
- In a pot for planting. There isn't anything to be concerned about if the installation is on the first level of a slab on grade structure. If there are numerous floor levels, however, the designer will need to collaborate with the structural engineer to ensure the structure's integrity is not jeopardized. On the following items, the landscape architect will need to collaborate with the engineer:
- The weight of the pot is made up of the pot, the soil media, and the water. If the tree is artificial, not only the weight of the pot must be taken into account, but also the steel tree supports and the ballast required to keep the tree steady. The diameter of the pot and the weight of the ballast required to overcome the horizontal tipping motion will determine the amount of ballast required. The criteria for horizontal forces will differ by the municipality, and the structural engineer should be aware of them.
- Plant weight — Palms weigh on average 100 pounds per square foot, and canopy trees can weigh even more. The tree might weigh 2,500 pounds based on a 25-foot palm.

- Plant growth - The weight of the plant will only rise as it grows.
- Weight of equipment - Because most plants are in pots, they require some flexibility to be moved. The machinery required to move the trees, such as a forklift, could be as heavy as the tree itself, doubling the weight in a given space.
- To keep the overall weight down, soil for planting in a planter should be light, such as vermiculite. Rather than filling the empty spaces within the pots and planters with soil, structural foam can be used to keep the weight down.

- **ACCESS**

Getting the plant material to its intended place is an important design element when putting interior plant material. While shrubs and groundcovers are usually not a concern, trees are an exception.

Trees can't always be wheeled into a structure due to their size. The size of the material you employ is restricted by the size of the doors that allow you to enter the building and the freight elevator that transports it between floors. Before the building is enclosed, large trees can be put by crane, but there is dust from construction, trash, and machinery to consider.

Plants will need to be cleaned regularly to allow light to reach the leaves, and barriers will need to be put in place to prevent machinery from hurting the plants and the containers they are in.

The removal of dead plants is usually not an issue because the plant material may be chopped up into manageable bits and transported using normal freight elevators.

- **MAINTENANCE**

A rigorous maintenance system must be in place to ensure plant success. The following concerns should be noted in maintenance contracts, including frequency, materials utilized, and durations.

- Watering
- Pruning and trimming Cleaning
- Fertilizing
- Insect and disease
- control Replacement

The landscape architect should evaluate the maintenance processes with the client and be familiar with them.

2.5.2 Types of Plants/Trees

The types of trees that can be used are discussed in the below Table 6.1

Table 6.1 Types of tress

PLANT NAME (LOCAL NAME)	(BOTANICAL NAME)	% REDUCTION OF CO2	AMOUNT OF ABSORBED BY THE PLANTS(KG)24 hours	AMOUNT OF CO2 ABSORB IN 1YEAR (FOR ONLY 1 PLANT)
1)PRAYER PLANT	Maranta leuconeura	14.40 %	0.0002677	0.097 KG
2)RUBBER PLANT	Ficus elastica	12.84 %	0.0002387	0.08 KG
3) BIRDS' NEST FERN	Asplenium nidus	12.48 %	0.0002320	0.084 KG
4)DUMB CAN	Dieffenbachia	11.10 %	0.0002063	0.07 KG
5)FLAMINGO LILY	Anthurium	10.80%	0.0002008	0.073 KG
6)ARROWHEAD PLANT	Syngonium podophyllum	10.08%	0.0001874	0.067 KG
7)PEACE LILY	Spathiphyllum	10.05 %	0.0001868	0.68 KG
8)GOLDEN POTHOS	Epipremnum aureum	10.03 %	0.0001865	0.068 KG
9)SPIDER PLANT	Chlorophytum comosum	0.10 %	0.0000019	0.0006 KG

3. CASE STUDIES

3.1 Indira Gandhi International Airport

In 2010-11, the airport handled 29.94 million passengers, and the planned expansion will bring that number to 100 million by 2030. The first phase of this development was the construction of Terminal 3, which would allow the airport to handle an additional 34 million passengers per year.

Figure 6.14 IGI Airport DELHI. (Source: Google Images)

Table 6.2 Details of IGI Airport

PROJECT	INDIRA GANDHI INTERNATIONAL AIRPORT
ARCHITECT	**Grimshaw, Nordic – Office of Architecture, Haptic and Indian practice STUP.**
OWNER	**Airports Authority of India (AAI)**
PROJECT TYPE	**PPP JOINT VENTURE**
BUILT-IN	**2110 HECTARE**
AIRPORT TYPE	**PUBLIC**
FLOORS	**2 FLOORS**
RUNWAYS	**3**
LOCATION	**DELHI**

Indira Gandhi International Airport, located near Palam, 15 kilometers southwest of the New Delhi railway station and 16 kilometers from the city center of New Delhi, is the Indian state of Delhi's primary international aviation hub. In terms of passenger numbers, it has been India's busiest airport since 2009. It is also the busiest airport in the country in terms of freight traffic. It was the world's 12th busiest airport by passenger traffic in 2018 and Asia's 6th busiest airport, with around 70 million people processed annually.

They're similar to taxis, except they're only available in specific locations and aren't allowed within the terminal. This mode has some limitations. Refer figure 6.15

Figure 6.15 Rajiv Gandhi international airport**.**
(*Source:* Google Images**)**

The Terminal 3 building can handle 34 million passengers annual [11].

3.1.1 Study of Airport (Arrival & Departure)

1) Typology:
Three-level building with terminal pier design.

2) Runway – The airport has three runways.

- Asphalt was employed as a material.
- 2.81*0.045 km, 3.81*0.046 km, and 4.43 * 0.06 km are the length and breadth, respectively.

3) Inside the structure (near the entrance): length 310m, breadth 50m, and edge 150mm higher above the road

4) Glazed frontage

- Greatest visibility to check-in areas

5) entry/exit – six entries; two additional staff-only entries; separate exit gates

- Entries; 2 additional staff-only entries; separate exit gates.

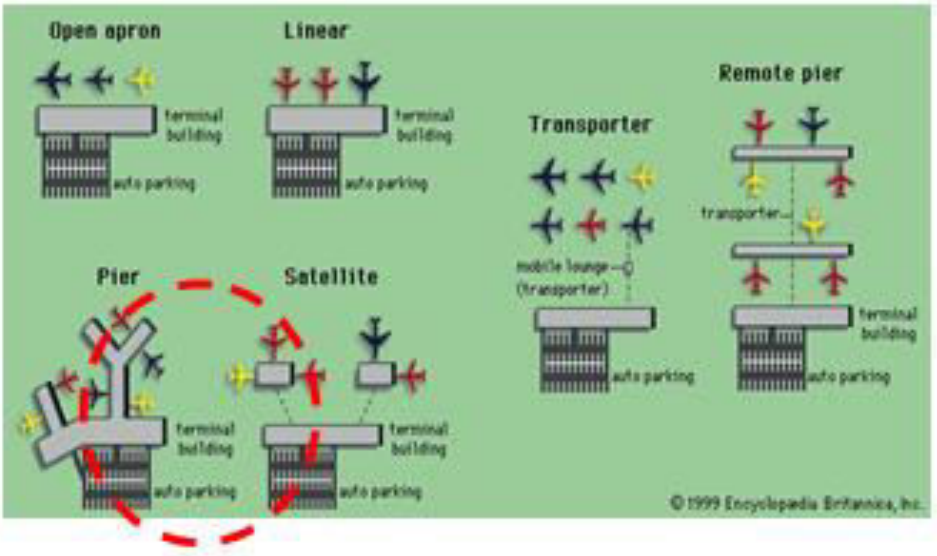


Figure 6.16 Parking bays details (11)

3.1.3 Emission Sources in IGI Airports

A. SCOPE 1: Emissions from airport operators

- Airport power plants, which provide electricity and heat/cooling
- Airport fleet vehicles, such as transfer buses and site machinery
- Building energy use, such as lights, HVAC, and machinery

B. SCOPE 2: AIRCRAFT EXEMPTIONS

- Emissions from aircraft engines during LTO, taxiing, and cruising

C. SCOPE 3: Other airport-related Emissions

- Most ground support and ground handling equipment
- Landside(off-site) ground access vehicles and trains [12]

3.2 Rajiv Gandhi International Airport, Hyderabad

3.2.1 Ecological Balance

A 273-hectare green belt has been constructed at RGIA, including a diversity of plant types. In addition, 971 hectares of natural greenery were maintained. In 2011 and 2012, RGIA received the State Government's finest landscape award for the second year in a row [13]. Refer figure 6.17

3.2.2Energy Conservation

- RGIA has saved 3.97 million kWh (kilowatt-hour) over the last four years through various energy conservation practices, reducing its carbon footprint by about 3331 tons per year. [13]
- LED lighting and the implementation of a building automation system.

Air conditioning unit optimization based on ambient temperature and weather conditions. [13]

Figure 6.17 Circulation plan.
(***Source*:** Google Images)

3.2.3Rainwater Harvesting

A net recharge rate of 1.729 million cubic meters per year is estimated. The utilization of surface water is an important part of water conservation.

- On the airside, runoff water from paved surfaces is collected in three principal drains.
- The overall capacity of the runoff water collection facility is 1,85,000 KL, and the water is processed with an Oil and Water Separator.
- The recharging basin contains ten recharge structures. Each building contains five recharge wells.
- Annual rainfall net recharge is expected to be 1.729 million cubic meters. [13]

3.2.4 Recycling and Solid Waste Management

- Composting of food waste generated at the airport on-site
- Instead of chemical fertilizers, compost and STP sludge are utilized as manure, resulting in a compost production of roughly 355 tons per year.
- Paper and plastic waste are collected and delivered to recycling centers.
- Used oil, e-waste, and bio-medical waste are disposed of at a State Pollution Control Board-approved facility, while used lead-acid batteries are sold back to dealers.[13]

3.2.5 Reuse & Recycle of Waste Water

- On the ground, runoff water from paved areas is collected and channeled into three large drains.
- The total capacity of the runoff water collection system is 1,85,000 KL.
- An oil and water separator is used to purify the water. The net recharge from rainfall is expected to be 1.729 million cubic meters per year, and the water will be used to clean and irrigate each structure [13].

3.3 Changi Airport:

Singapore Changi Airport, located 20 kilometers east-northeast of Singapore's core business district, is a key Asian aviation center. The airport is managed by Singapore's Changi Airport Group (CAG). The Civil Aviation Authority of Singapore (CAAS) [14].

- The Singaporean government made the decision to build
- As a result of traffic congestion at other airports, Changi Airport opened in 1975.
- There are three passenger terminals at Changi Airport, with a total capacity of 500,000 passengers.
- Each year, a total of 66 million passengers may be handled. 1st Station
- The first terminal opened in 1981, followed by the second in 1990 and the third in 2001

Terminal 3 opened in 2008. In 2008, Terminal 3 was opened [15]

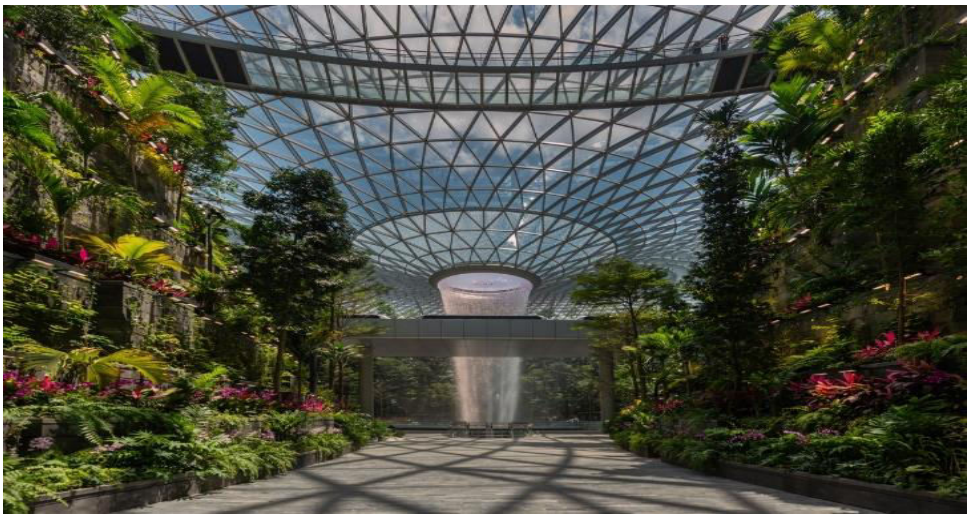


Figure 6.18 Jewel Changi Airport, Singapore.
(***Source*:** Google Images)

3.3.1 INTRODUCTION

Jewel combines two environments—an intense marketplace and a paradise garden—to create a new community-centric typology that serves as Changi Airport's heart and soul, while also serving as a link between the current terminals. Jewel emphasizes the airport's function as an uplifting and lively urban center, complementing Singapore's status as "the city in the Garden," by combining a sensation of being in nature with culture and leisure activities.

Landside airport operations, indoor gardens, recreational attractions, retail offers, restaurants, cafes, and hotel accommodations are all housed under one roof at the 135,700-square-meter hub. Because it is directly connected to Terminal 1 and Terminals 2 and 3 through pedestrian bridges, Jewel attracts both in-transit passengers and the general public. Each of the cardinal axes—north, south, east, and west—has a gateway garden-orient visitors and provide visible links between Jewel's internal program features and the other airport terminals.

SUGGESTIONS

Through the use of various techniques, the majority of airports have achieved their goal of sustainability and environmental friendliness [13].

The total study has aided in the development of several useful proposals for becoming green airports. They are as follows:

- Use of renewable energy sources for operations rather than non-renewable sources. Renewable energy sources such as solar and wind are more efficient, and their pollution contribution is negligible.
- Energy conservation strategies such as the use of LED lights and roofing with appropriate materials that collect and transfer energy. It is necessary to use energy-saving strategies such as lighting on demand.
- Wherever possible, reduce, reuse, and recycle, and adhere to a waste management policy.
- It is critical to ensure that no biodiversity is lost in the region that will be taken away for airport development, as well as no habitat for any species that will have an impact on the environment. Avoid natural heritage interventions that may hurt biodiversity.
- Preventing water shortages using water treatment facilities and rainwater harvesting systems; reducing noise emissions through various noise mitigation measures.
- Aeroponic farming and interior landscaping will be grown in airports. Plants are grown without the use of soil in this style of gardening. Roots in this vertical farming system are misted with a nutrient solution during a regular watering cycle.
- Rather than beginning from scratch, prioritize environmental integration, restoration, and upgrading of existing infrastructure. This can help to protect soil resources and decrease soil and groundwater degradation.
- Developing more standards, such as LEED, that airports can receive if they take innovative ways to meet their sustainability goals.
- Encouragement of programs and standards established by entities such as the DGCA to monitor airport performance and pollution levels.
- Biofuel consumption for airside vehicles and advancements in efficient flight monitoring systems to reduce flight take-off and landing times.
- Encouragement of private sector initiatives for infrastructure and raising awareness among students.

4. CONCLUSION

There was one live study and three net studies. All of the airports were different types, and each had its distinct qualities. It also met the criteria for both enhanced and new airports.

A green building is environmentally friendly because it employs particular concepts during the design, construction, and operation phases that allow it to derive maximum benefit from the environment while causing the least amount of harm [17]. When developing a green building, numerous things must be taken into account. It is critical to understand how effective a project is in terms of environmental friendliness. The proposed method would assign a score to the building based on a variety of parameters, giving a good idea of where it stands in terms of being a green building. Green building approaches should be used in the construction of all new buildings to the extent possible. When constructing a structure, builders and developers should use renewable resources, recycle wastes and water, and use cost-effective building processes, among other things [14].

Existing green building rating systems should be expanded to include old buildings that have already been built. If this is not the case, a new rating scheme for old structures should be devised [11]. A new ranking system for small-scale initiatives that take into account the perspectives and needs of small cities should be developed with the local context in mind. People's and developers' interest in green building techniques may increase as a result of this.

The airline industry has paved the way by being more comfortable and saving time. To accommodate this ever-increasing demand, airports have progressed. This increase will provide significant environmental and sustainability issues in the next years. It is critical to work toward achieving sustainable development and protecting environmental health by taking actions to remove the risks that this industry poses. Green airports are the most effective way to address the problems that plague the aviation industry [10] It's all about creating a long-term ecosystem for the airport and its environs. Long-term efforts must be backed up and carried through.

REFERENCES

1. AubinLopez. (2016). "Vulnerability of Airports on Climate Change: An Assessment Methodology" Transportation Research Procedia, 24-31.
2. Baxter, G. (2022). "An Analysis of the Annual Carbon Dioxide Emissions (CO2) of a MajorEuropean Hub", International Journal of Environment, Agriculture and Biotechnology, 098-117
3. Nils Böckler, Jens Hoffmann, Andreas Zick (2015) Airport: A Case Study of Frankfurt Airport.International Journal of Agriculture Environment and Biotechnology 7(1), 98-113.
4. Baxter, G. (2022). Towards sustainable airport waste management through the adoption of a "green"airport strategy: The case of Incheon International Airport. Clean Technologies and Recycling, 247-278.
5. Betul Kacar, E. T. (2022). "Green Airport building certification comparison: a practical approachfor Airport Management". International Journal of Green Energy.
6. Ching-Cheng Chao, T.-C. H.-C. (2017). "Indicators and evaluation model for analyzingenvironmental protection performance of airports". Journal of Air Transport Management, 61-70.
7. Dimitrios Dimitriou, A. K. (2022). "Assortment of Airports' Sustainability Strategy: AComprehensiveness Analysis Framework". Sustainability,1-5.
8. DucksuSeo. (2021). "Articulate Design Thinking for Sustainable Airport Environment: A CaseStudy of Singapore Changi Airport T3". Transportation Research Procedia, 136-142.
9. Ferrulli, P. (2016). "Green Airport Design Evaluation (GrADE) – Methods and Tools ImprovingInfrastructure Planning". Transportation Research Procedia, 3781-3790.
10. Fiona Greer, J. R. (2020). "Airports and environmental sustainability: a comprehensive review. Environmental Research", Environmental Research Letters, 1-24.
11. Li Ke, S. B. (2020). Research on planning and design of airport airfield area. Material sciencesand Engineering.1-10.
12. Maria Nadia Postorino, L. M. (2014). A transport carbon footprint methodology to assess airportcarbon emissions. Journal of Air Transport Management 37, 76–86.
13. N. Sumathi, M. P. (2018). Green Airports- Solution to Stop Pollution! International Journal ofLatest Technology in Engineering, Management & Applied Science (IJLTEMAS), 78-85.
14. Sema Kayapinar Kaya, N. (2020). Futuristic airport: A sustainable airport design by integratinghesitant fuzzy SWARA and hesitant fuzzy sustainable quality function deployment. Journal of CleanerProduction.
15. Stephane Louise Boca Santa, J. M. (2020). A Green Airport model: Proposition based on socialand environmental management systems. Sustainable Cities and Society.1-15.

Chapter 7

VERNACULAR IDENTITY IN CONTEMPORARY ARCHITECTURE (COMPOSITE CLIMATE)

Charu Jain[*] and Aniket Rana
[1]Professor, Delhi Technical Campus, Greater Noida, India
[2]Student, Delhi Technical Campus, Greater Noida, India

ABSTRACT
Our growing world faces many challenges related to the environmental crisis, climate change, globalization, mass migration, urban housing and technological development. Native architecture is therefore similar to using native materials without the use of imported components or processes, as they are built by natives who understand the needs of a particular location and climatic conditions. As the world slowly moves toward globalization and urbanization in the 21st century, the world is slowly becoming a global village, and traditions and cultures are losing their regional peculiarities. Therefore, the presence of indigenous architecture leads to some questions. Adapt or adapt to a changing ecological and cultural environment? Will it be demolished and replaced with a more modern building? So, with all this in mind, we need an architecture that can solve the problem both ways. Firstly, to meet the current demands of the latest growth technologies, process lessons learned from the past, and solve a variety of 21st century problems. Secondly, a climate- and culture-sensitive, cost-effective building environment is a good building. Therefore, creating a collection of contemporary and colloquial forms can lead to more effective architectural forms. This allows us to better understand the needs of the current generation of places, without compromising the place's general occupation.

Keywords: Globalization, global village, vernacular traditions, urbanization

1. INTRODUCTION
In the 21st century, the world is slowly becoming a global village, with traditions and cultures losing their local character. Many questions arise about the existence of indigenous architecture.

Will it adapt to a changing ecological and cultural environment, or will it simply disappear?

Will it be eradicated and replaced by more modern buildings, or will it just be such an architectural spectacle in a museum?

It will take many hours before we can use colloquial language as a model of sustainable development that combines valuable modern technology with valuable lessons from the past to solve the problems of the 21st century. As ever, rural architecture is a work of the past, often stigmatized as images of poverty and backwardness, conveniently replaced by the lack of more advanced and modern buildings. Although attractive to the house and scholars of anthropology and sociology, it is rapidly losing relevance to the communities that house it. Vernacular architecture can be defined as the pinnacle of creativity.

A process of interpreting building traditions, skills and experiences. It is strongly influenced by factors such as environmental conditions, material resources, social structure, belief systems and behavioural patterns, and social and cultural practices.

3. Vernacular Architecture: Value and Significance

Figure 7.1 Kutch- Bhungas
(*Source:* dsource.in https://www.dsource.in/**)**

The most commonly understood meaning of indigenous architecture is owner and occupant, or community itself. It is generally inexpensive and designed according to the climate and socio-cultural community that hosts it.

This type of architecture includes apartments, public spaces and entire settlements. Vernacular architecture, often referred to as "architect-less architecture," includes structures created by empirical architects without the intervention of professional architects or the use of industrial components [1].

"Vernacular architecture includes people's dwellings and all other buildings. In relation to environmental conditions and available resources, they usually use conventional techniques. Ownership or community construction. All forms of indigenous architecture are built to meet specific needs and to respond to the cultural values, economies and lifestyles they generate" [2].

According to Brunskill (2000), one of the regional and national features that has survived the various political mergers that make up the country today is due to indigenous architecture. Since the 1960s, there has been a focus on identifying and documenting this heritage.

A diverse architectural expression of form and structure throughout the settlement, with simple, unpretentious, densely packed houses along gently curving streets like Santorini in Greece or Casares in Spain, is like Renzo's piano. Inspired architects.

That was the source of the ration. Frank Wright, Le Corbusier. Aesthetic diversity is created not only by the juxtaposition of Building his blocks and volumes, but also by the region's local handicrafts, such as Warli's paintings, mosaics and tile work.

2.1 Socio-Cultural Aspects

Vernacular architecture is a concrete manifestation of society and its culture. Studying his anthropology highlights the nuances of human behavior and his beliefs in architecture. Traditions transcend each other in traditional town planning and architectural representation of popular architectural forms. "There are various concentric rectangular temple towns in and around Tamil Nadu with a large Hindu temple in the center. These are described in the ancient Sanskrit text Sylpashastra. It is considered a city built according to ideal city planning. Cities and temples that reflect cosmology are common, but show such a clear concentric form that symbolizes the structure of the universe on a city scale.

For example, The City of Jaipur's Grid Iron Plan is also based on an old Hindu text that defines a rigorous geometric plan according to the Mandala concept [3].

In the temple cities of South India, rituals and festivals played an important role in shaping the social and spatial nature and form. The basic principles of urban form of a historic temple city. The most eloquent example of this is the temple city of Madurai. Five Minakshi Sundareshwara temples are located in the center of the city.

Figure 7.2 Rambagh palace Jaipur
(*Source:* kamlan Travels**)**

2.2 Materials and Construction

India's geographical and cultural diversity has brought about different types of vernacular architectural representations, depending on the climate and locally available sources. The use of materials in vernacular architecture has been extensively studied and published. The next section gives an overview of the types of materials used in the construction of different homes.

2.2.1 Mud

Mud is the most common form of indigenous building material and has been found as a major material in the hot and dry regions of India. Mud is often preferred due to its dual nature of being malleable when wet and hard when dry. Mud is also used in combination with cow dung, grass, straw, straw, gravel, etc. to increase its strength. The sludge structure is also refractory and good noise absorbent.

2.2.2 Brick and Terracotta

The rich alluvial soil of the Indo-Ganges Plain is the main reason for the widespread use of bricks in the plain. Burnt bricks have been used for construction since the days of Mohenjo-Daro and Harappa.

Punjab Cultural Landscape is patterned in a brick kiln and is widely used as a common building material for buildings in North India. Bricks were not only used for masonry, but also for the manufacture of structural elements such as domes, vaults, columns and arches. Bricks have a variety of uses, from making jalis to providing privacy and air circulation in the courtyard of the House.

2.2.3 Stone

Stone is another material widely used in Indian vernacular architecture. Each area has certain types of stones used for construction. Stones are used in the construction of structural parts such as masonry walls, floor slabs, lintels, beams, columns, arches and domes. There is also a way to eliminate the need for mortar using interlocking stones, and in some cases large monolithic stones are used to create structural elements such as columns and beams. In the desert area, the most common stone used in indigenous architecture is yellow sandstone.

2.2.4 Timber

The use of wood in Indian vernacular architecture is common in almost all climates. Softwoods such as cedar are popular for construction in Kashmir and Himachal, while rosewoods such as Sheesham and monkeys are popular in the Punjab and Indian Ganges plains, while Burma teak and jackfruit are widely used in southern India. Palm trees and bamboo are spread not only in Bengal but also in coastal areas.

Furthermore, natural materials are used in different places according to geological conditions adding a native touch tradition to a space.

2.3 Composite Construction

Advances in technology, transportation and telecommunications have made it possible for modern materials to reach the innermost part of India. This paved the way for a new type of construction that could be called a compound. This technique combines vernacular and modern materials to create new typologies of vernacular.

For example, the Ladakh trombe wall is a thick south-facing mud wall with vents at the top and bottom. At the top there is usually a glass window that allows sunlight to enter the room, and the masonry ensures that it is absorbed and radiated slowly, providing so care for the comfortable climate of the interior. To do. Similarly, modern technology encourages the use of tarpaulins as part of the patio's waterproofing to prevent water from rain and snow from penetrating the ground below. Similar innovations have been observed in the eastern region, where bamboo matted corrugated sheets are used for roofs, and bamboo fittings are further secured using J-bolts, screw bolts, and the like.

2.4 Contemporary Vernacular Architecture

The architecture by the people, people's architecture is fundamentally different from the image linked to the vernacular community. Changes in economic and social patterns have made the availability of materials manufactured nationwide and have brought about major changes in vernacular architecture in many regions.

The spread of cement concrete, galvanized iron, stone and brick has brought new meaning to vernacular architecture. In the Uttar Kashi district of the Himalayas for example, the country slang has shifted from the roof of the slate. To the galvanized tin roof throughout the landscape. Due to lack of resources and high prices, flat concrete roofs or sloping cement concrete roofs are preferred over wooden roofs.

"In Ladakh, the use of flat glass is increasingly changing the shape of traditional buildings, creating" space "for winter warmth, and incorporating plastic pipes into the water supply and drainage systems of native buildings [4].

The dichotomy of the situation is to understand what is available locally [5].

For example, conservationists often prescribe lime as a building material rather than cement. But in reality, lime is not readily available and requires a long process to manufacture, but cement can be purchased at stores in the most remote villages [6].

The Materials and craftsmen who have the ability to make and use lime have also declined over the years, making them more expensive products. So, the question is what is locally available, cheap and sustainable. A similar situation occurs when using stones. For environmental reasons, stone quarrying is banned in many areas, and therefore, because there are no locally available stones, the general public relies on the use of bricks or imports stones from elsewhere [7]. Therefore, it is used by the general public as its main building material.

What is today's Vernacularism in a Changing Social, Economic, Political and Natural Environment?

2.5 ADVANCE INTERVENTIONS

2.5.1 Solar Passive Design

By incorporating solar passive technology into the design of the building, stress on traditional systems such as heating, cooling, ventilation and lighting can be minimized [8].

Passive strategies provide thermal and visual comfort by leveraging renewable energy sources and sinks. Examples: sunlight, outside air, wet surfaces, vegetation, etc. Meaning in a complex climate: The purpose of an architect is to design a building so that it has maximum sunlight in winter and decreased in summer. Maximize natural ventilation.

2.5.2 Compactness

The shape of the building also determines the airflow pattern around the building. This directly affects the ventilation of the building. Building compactness is measured by the surface area to volume ratio (S / V). The depth of the building also determines the need for artificial lighting. The greater the depth, the greater the need for artificial lighting.

2.5.3 Sheltering or Self-Shading

Designed to be self-shading by mass or articulation, the build form becomes a protected build form that blocks much of the direct sunlight. In mixed climates, envelopes should be designed to be shaded all day long. The outer walls should be planned to be shaded from each other.

2.5.4Orientation

For solar passive design features, orientation is an important design consideration, primarily in terms of solar gain, sunlight, and wind. In tropical climates like India, the long facades of north-south buildings are preferred. East and West receive the greatest sunlight in the summer [9]. Vertical facades from north to south are also recommended, as the south facing area receives maximum intensity of sunlight in winter, mainly in cold climates.

Further for Better Understanding Few Case Studies are Coated Below.

4. CASE STUDIES

3.1 THE WALL HOUSE, AUROVILLE

ABOUT THE ARCHITECT

Anupama Kundoo is an architect of Sir J / School of Architecture in Mumbai and has Datone at the Baked Mud In-situ Houses of India at the Berlin Institute of Technology. In 1990, her architectural firm focused on materials research with the aim of decreasing impact of building technology on environment. An innovative approach backed by experimentation and intensive research, from the development of building technology and the integration of energy and water efficient building solutions to the construction of environmentally sustainable and socio-economically beneficial prototypes10 architecture Site.

Area…	15 acres (total area of community)
Built up area…	100 sq. m.
Cost	Rs.1 million
Architect	Anupama Kundoo

The philosophy of structure hinges on developing a structure this is energy- efficient, Climate responsive and makes use of green substances and opportunity constructing technology [10]. The idea of the wall is the skinny line among the general public and the private. Here, the

innovation lies with inside the definition of the constructing programme for a residential residence and the transition areas among the interior and outside. Borders and transitional areas were described in a brand new way. Refer in in figure 7.3 and 7. 4.

Figure 7.3 Wall House. Image © Javier Callejas
(*Source:* https://www.archdaily.com/880897/anupama-kundoo- current-methods-of-construction-are-producing-more-problems-than-solving-it**)**

Figure 7.4 Open bath that blends with nature
(***Source:*** https://www.re- thinkingthefuture.com/know-your-architects/a453-15-projects-by-anupama-kundoo/)

This imbalance is driven by the adoption of expensive, un environmental high-tech buildings and space-efficient low-tech jargon for a growing population. Based on extensive research and experimentation, Wall House has managed to strike a balance by exploring new ways to use local materials.

The building is an example of modern architecture that meets international socio-economic requirements while reducing its environmental impact. Technological advances that can be made by unskilled workers serve as prototypes for understanding how to optimize resources and space.

3.2 GAIROLA HOUSE

3.2.1Project brief

The Gairola House is a multi-family semi-detached apartment stack, constructed purely for rental purposes, located in Gurgaon, Haryana.

3.2.2 About Architect

ANAGRAM ARCHITECTS is an award-winning spatial design studio, internationally recognized as one of the world's premier emerging offices, offering innovative context-specific designs that promote a sustainable lifestyle. They aim to enrich the elementary modernity with traditional and Unconventional practices while developing culturally relevant, contextual and resource-efficient designs [11]. Their practice is based on a complete sustainability philosophy that fits the economic, sociocultural and environmental contours of the project. Refer figure 7.5.

Figure 7.5 Gairola house
(***Source:*** https://architizer.com/idea/361489/)

ARCHITECTS:	**Anagram Architects**
PROJECT:	**Gairola House**
LOCATION:	**Gurgaon, Haryana, India**
STRUCTURE:	**Trabeated structure in concrete (Cast in situ) and brick masonry**
EXTERIOR FINISHES:	**Terracotta cladding tiles, stone cladding, painted cement plaster, exposed bamboo screen**
INTERIOR FINISHES	**Cement Plaster, polished stone flooring, ceramic tiles**
SITE AREA:	**299 sqm.**
COVERED AREA:	**523 sqm.**
CONSTRUCTION PERIOD:	**June 2008 – Feb 2009**
COST OF CONSTRUCTION:	**INR 9,000,0000 /- (Rupees Nine million only)**

3.2.3 Design Concept / Project Description

In most Indian cities, the typical townhouse or apartment block evolves from semi-detached single-family homes built on suburban or suburban lots. The planned and unplanned development of this urban sprawl is caused by the inevitable accumulation of planned development. The farther out the city suburbs are moved and the better the connections to the city, the smaller the perceived distance between these developments and the city center. Due to the subsequent increase in rental values, the apartment has been divided into several rental units. Refer figure 7.6.

Figure 7.6 Vernacular Elements
(***Source:*** https://architizer.com/idea/361489/)

As suburban dwellings, their designs mostly follow the type of fortified units with introverted courtyards, high privacy and maximum floor slab area. This limits all social relationships with neighbors to cross-border joint conversations.

The typology thus evolved into a stack of apartments with the same floor plan and shared staircase, usually ignoring the role of stairwells, courtyards and alcoves as common areas. The residence was to be developed exclusively for the rental market.

Our designs use exterior volumes as shared resources (for light and ventilation) to meet the needs of residential privacy and individuality while promoting a vibrant and socially connected urban lifestyle. Explore the possibility of creating a sending stack.To maximize rental options, the stack is designed as a 4-bedroom, 2-bedroom 1-floor, and 1-bedroom penthouse duplex to accommodate typical tenants such as small families, young couples, single professionals, and students. Corresponds to the base [12].

The client wanted to develop this property specifically for the rental market. This design is for residences that use exterior volumes as shared resources (light and ventilation) to facilitate a vibrant and socially connected urban lifestyle while meeting the need for privacy and individuality. Explore the possibility of creating a sending stack. Refer figures 7.7 & 7.8.

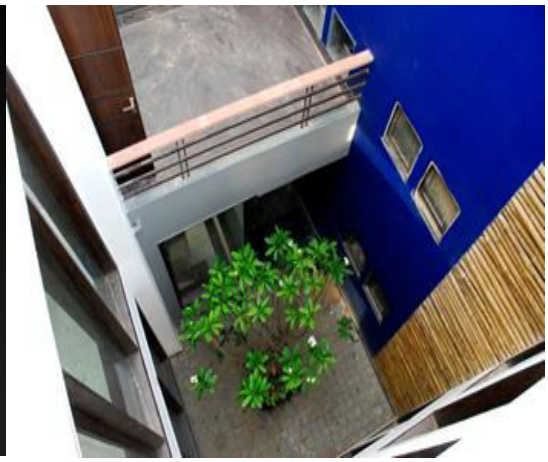



Figure 7.7 & 7.8 Central courtyard
(***Source:*** https://architizer.com/idea/361489/)

3.2.4 Flexible Leasing

To maximize rental options, the stack is designed as a 4 bedroom duplex, 2 Bedroom single level unit and 1 bedroom penthouse. This is ideal for small Families, young couples, single professionals and students. It help accommodate a typical tenant base.

3.2.5 Socialties and Individuality

Because apartment floor plans aren't the same, the typical courtyard-porch Setback is no longer a simple rectangular block, but a multi-story social flower Space.

The forward setback volume is divided into multiple spatial clusters that are more interconnected by manipulating closed and open volumes. The open staircase connects to the stepped central courtyard for the shared space of the shared territory. Care was taken to limit the increase in line of sight to the more public areas of the apartment. A sheltered sunken courtyard, a cantilever porch and a roof terrace garden provide each apartment with its own outdoor space. Each apartment is designed to be a unique home, but encourages a socially vibrant lifestyle.

Figure 7.9 Façade in vernacular contemporary style
(***Source:*** https://architizer.com/idea/361489/)

3.2.6 Inferences

1. **Use Items as Needed:** The play of animation with volumes and voids is further demonstrated by the juxtaposition of materials and textures. Surface cladding patterns are detailed to allow the introduction of fenestration and windows.
2. **Providing Environmental Space:** Protected courtyards, cantilevered porches and roof gardens give each apartment its own space. Each apartment is designed to be a unique home, yet encourages a socially active lifestyle.

4. CONCLUSION

In this world of modernism, the world is becoming a global village, and traditions and cultures are becoming less local. Many questions arise about the existence of indigenous architecture. Will colloquialism simply disappear, or will it adapt to changing ecological and cultural environments? Will it continue to be stigmatized as an image of poverty and backwardness, or will it be eradicated and replaced by more modern buildings?

In a rapidly developing economy, we are facing an environmental crisis. Climate change, globalization and mass migration have raised concerns about the relevance of indigenous traditions in modern life.Vernacular traditions are creative processes, developed through the interpretation of knowledge and experience from the past, negotiated and adapted by generations to meet the needs and challenges of the times. Vernacular architecture is the physical manifestation of environmental, social and economic constraints and forms an important part of human evolution.

The dynamic nature of our native traditions allows us to constantly evolve and adapt to changing socio-cultural environments. These traditions are inherently sustainable and contain valuable lessons that can be applied to contemporary architectural practice.

This research paper, Vernacular Identity in Contemporary Architecture (Composite Climate), combines valuable lessons from the past with equally valuable modern technologies to solve the problems of the 21st century, in a model of sustainable development. The introduction focuses on the concept of sustainability and attempts to highlight the sustainability inherent in Indian architecture. Literature and case studies by contemporary architects such as Anil laul, Anagram Architects, Sanjay Prakash, Matthijis Cornelissen, Vinod gupta, and Anupama Kundoo, where local traditions are incorporated into contemporary architectural practices to create sustainable buildings.

REFERENCES

1. Singh, S. (2021). “Sustainable construction techniques used in vernacular architecture”, Rethinking the Future. 1-10
2. Studio, K. D. (2017,). “The Mud House - (Katchi Kothi) and Anangpur”, Kamath Design publication.
3. Ghodsi, H. (2012). “Vernacular Architecture: Solution to a more sustainable future”. Research gate Masters of Architecture thesis.1-15.
4. Jindal, I. (2020). Why architects must study Vernacular Architecture?”. Rethinking the Future.1-10. https://www.re- thinkingthefuture.com/rtf-fresh-perspectives/a2252-why-architects-must- study- vernacular-architecture/
5. Salman, M. (2018). “Sustainability and Vernacular Architecture: Rethinking What Identity Is” IntechOpen. Https: //www.intechopen.com/chapters/64381.
6. Asadpour, A. (2020). “Defining the Concepts & Approaches in Vernacular Architecture Studies”. Universitar Islam Negeri Alauddin Makassar.

7. Rahim, M. (2020). Bioclimatic and Sustainable Features on Vernacular Architecture in Ternate. Materials Science and Engineering, 1-8.

8. Kawathekar, V. (2020). "Vernacular Architecture in India: Architecture of the masses", National Conference of Traditional Knowledge Systems of India, 1-7. https:// www. researchgate.net/publication/343078894_Vernacular_Architect

9. Singh, S. (2021). "Sustainable construction techniques used in vernacular architecture", Rethinking the Future. https://www.re-thinkingthefuture.com/sustainable-architecture/ a2799- sustainable-construction-techniques-used-in-vernacular-architecture/

10. Long John, Desai Madhavi & Deasai Miki. (1997). Architecture & Independence, The Search for Identity, Oxford University Press.1-12.

11. Udamle Sanjay. (2003). "Architecture for Kutch, Reinterpreiting the Lifestyle, Culture, Crafts and Architecture of Kutch Region in New Housing Sanjay Udamale", Architecture research.

12. Volwahsen Andreas. (2001). Cosmic Architecture in India, the Astronomical Monuments of Maharaja Jai Singh II, Prestel.

Chapter 8

EXPLORATION OF SENSES AT VARIED SCALES: ADOPTING A MULTISENSORY DESIGN APPROACH IN RECREATIONAL SPACES

Preeti Nair[1] * and Ritik Sharma[2]
[1]Associate Professor, Delhi Technical Campus, Greater India
[2]Student, Delhi Technical Campus, Greater Noida, India

ABSTRACT

A public garden or a public street garden is not just a simple area but a space that stimulates all of our senses. The relationship between people and spaces is constructed through the alteration of spaces. This relation is made through experience and it is the senses that assist our inexperience. The multisensory experience of users in recreational spaces is described by my dissertation topic Exploration of senses at varied scales: adopting a multisensory design approach in recreational spaces, the aim is to understand the senses in architecture and how we can enhance the experience of users through incorporating of senses in recreational space.

To understand the multisensory experience of users firstly we need to know how many senses we have. According to Aristotle, we have the basic five senses – smell, sight, touch, taste, and hearing. Most architects typically design spaces with only two or three of our five senses namely, sight, touch, and hear, in which the visual sense is dominating. For example, if we visit a garden, and we mark each sense over there we will get wonderful results,

For vision, colorful flowers and planters are used everywhere

For smell, it's the flowers, which give a pleasant fragrance

For taste, there is a food stall or canteen

For sound, trees used that attract birds

For touch, different combinations of materials used

Using all our senses to design a recreational space will enhance the user experience of interacting with different spaces. Spaces that support all five senses are termed successful and comfortable places.

Keywords: Sensory scales, Design Parameters, Recreational Spaces, Multisensory spaces, Space utilization

1. INTRODUCTION

In the 1950s, the first use of multisensory design can be seen in Europe and Japan through the work of Zero and Gutai. They are a post-war artist and radical, they have realized that sight alone is no longer able to recognize art, and started out working with the five senses. Zero work using light, sound, and optical illusions to stimulate all our senses and they believed that artwork has to contain full human participation [1].

Architecture is noticeably affected by using the way it has to be experienced. When there is a dominance of one sense over another, it impacts the entire architecture. Any architectural space is influenced by when there is one sense dominating or there is a loss of a unique sense. If a building is experienced by only those people who have lost one of the senses, then its architecture should reflect it. So, architecture to be universally experienced by means of all sorts of human beings has to be multisensory [2].

This dissertation aims to understand how the experience of users can be enhancing through our senses by understanding the senses in architecture. Why recreational spaces? Because it is the

space where all ages groups of people and those people who have lost their one of the senses comes here to interact, to understand how it is benefit to users, and how it will affect the life of that architectural space, to understand after incorporation of senses in recreational space the user's footfall increases of decreases.

2. METHODOLOGY

Detailed methodology chart is shown in figure 8.1.

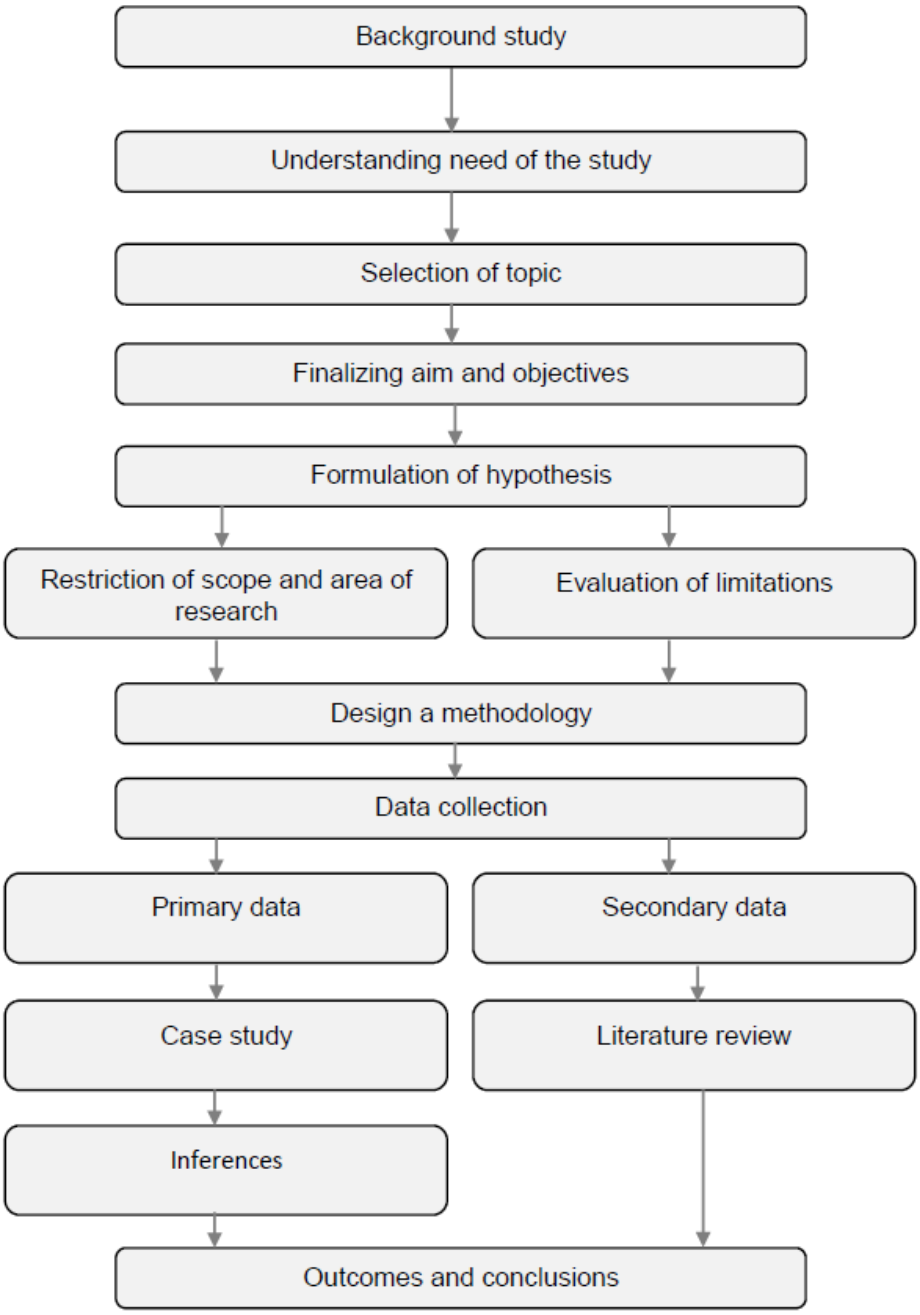


Figure 8.1 Detailed methodology.
(***Source:*** Author)

3. Architecture and Human Senses

Refer figure 8.2 for architecture and human senses details.

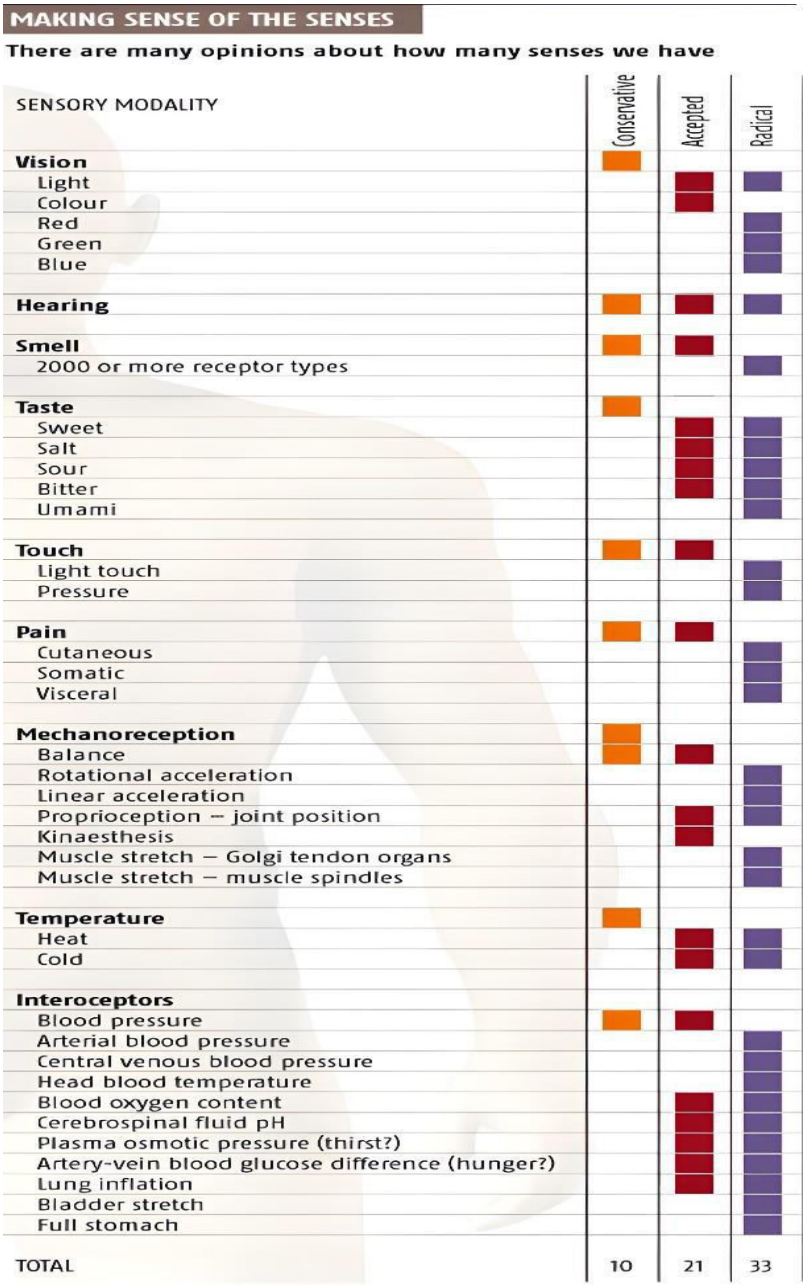


Figure 8. 2 Senses table. [3]

Architects believe more in visuals. Unfortunately, various sensations are often ignored. This is a shame as architecture can have a huge impact through the senses. For example, a building can be more absolutely associated with the surrounding traditions through all senses. Exploring historical, traditional, or contemporary cultural patterns can lead to the success of architectural works, if the senses are no longer ignored [3].

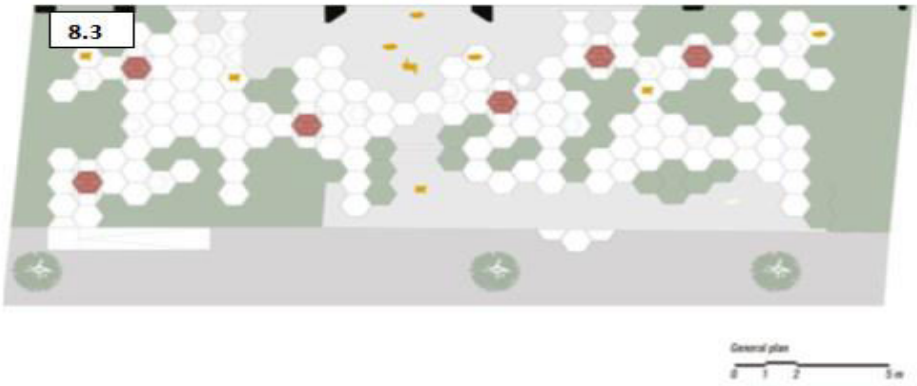
Architects need to act as a composer, synchronizing function and beauty to adjust the space using the senses, and how the human body feels in this space is most important. Architecture has come to life as the human body interacts with the spaces using all of our senses [4].

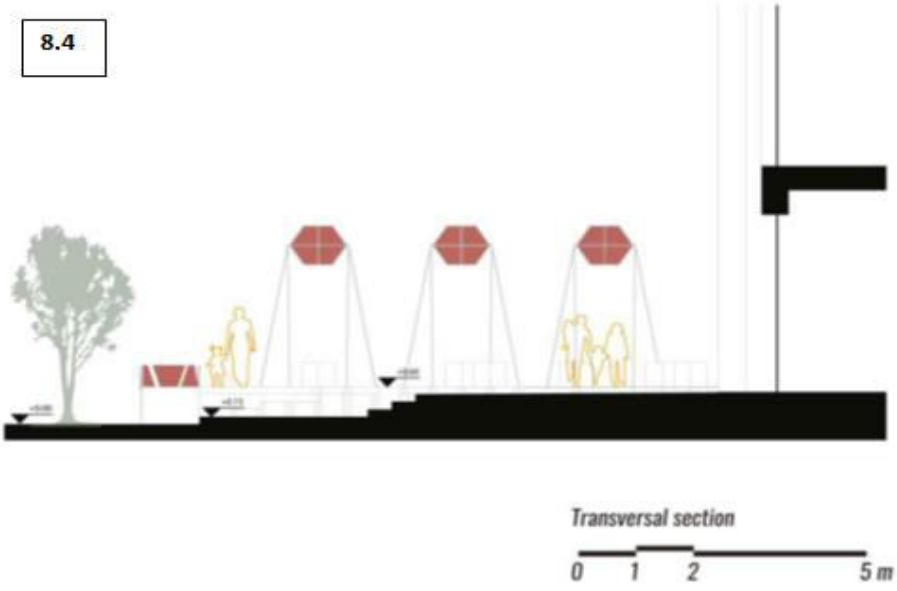
Architecture can be perceived by the resident as the end result of the composition of the architect, or as the arrangement of all the sensory characteristics of the space. Placing spatial sensory functions allows architects to guide residents through the functional and aesthetic rhythms of the created site. Building of all sensation help move residents and improve their experience [5].

Architectural space is a layer of all sensations. Similar to music, spatial points combine to form a symphony that residents can experience. The features and shapes of architecture are no longer primarily useful for visual sensations. The experience also allows for a more complete representation of all sensations, shapes and functions, allowing residents to experience deeper and more meaningful moments in which they feel the surrounding bouquet in all dimensions increase [6].

4. DESIGN CONCEPT

Landscape architects and designers thinking, how can we built a relationship between user and nature through design? They came up with the idea 'Zighizaghi', a space that replicates some natural element or shapes. There are three partners, Miliashop, Italian Furniture brand, and Farm cultural park art gallery and they wanted to express its connection with nature, OFL architecture Design this urban garden of 320 sqm so accurately in the form of honeycombs. Refer figure 8.3 to figure 8.6.





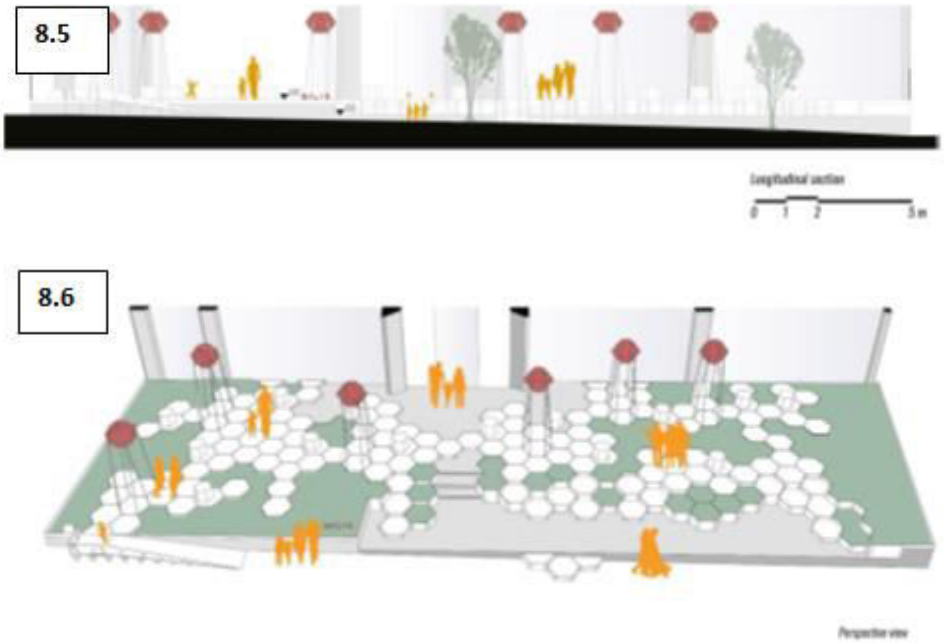


Figure 8.3-8.6 various stages of design concepts (Source: Google Images)

This explanation is completely justified, as all the details are in one place. Many senses are filled, including sight, hearing, smell, and even touch. The color combinations are correct-not too many, not too few, with the help of lighting. The space is calm, but really dynamic and lively, as depicted in Figures 3-6. Different types of plants enhance the sensory experience with scents, and enrich the space with sensory experiences. Music is used to stimulate auditory experience. Always useful and recommended for this type of landscape.

5. CONCLUSION

Architecture is a medium through which we are designing the space for people and constructing relationships thru the alteration of spaces, this relation is made through experience with the help of our senses. Using senses in architecture is not new, if we compare modern architecture with the architecture of the previous eras, there is a lack of using senses in modern architecture.

In modern architecture, there is a dominance of visual sense over other, because most of the design deals with only aesthetics. Let's talked about it in the context of recreational spaces, because this is the space that most people have visited. All the architectural design is visual bias it is not true, all the senses are dependent on each other and every space is a sensory space, which stimulates our vision, auditory, olfactory, gustation, and tactile sense.

Let's take an example of a garden there are a lot of colorful flowers used to stimulate the visual sense, but there is an involvement of other senses to enhance your experience, if any person touches the flower or plants and material there is an involvement of tactile sense, the sound created by walking on pathways stimulates auditory sense. So to create a better multisensory recreational experience we need to understand that all of our senses are important because it helps in experiencing the spaces. If there is an involvement of all of our five senses so the experience is unforgettable, but again there is a lack in designing multisensory recreational spaces, this can be understood through case studies, there is limited usage of some senses like smell and taste. With the help of literature and case studies, we can understand how we can incorporate all of the senses into recreational space to create a multisensory experience.

Some methods to improve sensory experience of all five senses are as follows-

Visual Sense- colorful flowers and different color combinations can be used and attractive shapes and iconic spaces like water bodies, sculptures can be used to stimulate the visual sense

Tactile Sense- use of different textured materials in different spaces to tell about places, different shrubs, and vegetation can be used, tactile sense is very strong in all of the senses, and it is very helpful for those who have lost their visual sense.

Auditory Sense- using trees that attract birds and water body and water body and speakers can be used to stimulate the auditory sense, Ira Keller fountain where auditory sense is stimulated by the water fountain, Zighizaghi where the speaker is used to enhance the auditory experience

Taste Sense- this sense is hard to incorporate at all places but we can incorporate it in some areas, by planting fruit trees and designing food stalls and canteen.

Smell Sense- this sense can be incorporated by using wood that gives fragrance, for example - Lebanese cedar, atlas, cedar juniper, etc., and fragrance flowers can be used, for example - rose, lavender, etc.

By incorporating senses by using different materials and design techniques in recreational spaces it will enhance the user experience of interacting with different spaces.

REFERENCES

1. Charles Spence (2020). Senses of place: architectural design for the multisensory mind. Cognitive Research: Principles and Implications volume 5.
2. Tianchen Dai, Xing Zheng (2021). Understanding how multi-sensory spatial experience influences atmosphere, affective city image and behavioural intention. Environmental Impact Assessment Review Volume 89, 1-6.
3. Jaakko Ranne (2019). Designing for Multi-sensory Experiences in the Built Environment. DOI: 10.13140/RG.2.2.26244.35208
4. Charles Spence (2020). Senses of place: architectural design for the multisensory mind. Cognitive Research Principles and Implications 5(1):46. DOI: 10.1186/s41235-020-00243-4
5. Jian Xu, Lingyi Chen, Tingru Liu, Tao Wang, Muchun Li and Zhicai Wu (2022). Multi-Sensory Experience and Preferences for Children in an Urban Forest Park: A Case Study of Maofeng Mountain Forest Park in Guangzhou, China. Forests, 13(9), 1435; https://doi.org/10.3390/f13091435.
6. Siyi Wang (2020). Museum as a Sensory Space: A Discussion of Communication Effect of Multi-Senses in Taizhou Museum. Sustainability, 12(7), 3061; https:// doi.org/ 10.3390/ su12073061.

Chapter 9

HEALING THROUGH ARCHITECTURE IN HEALTHCARE

Gandharva Swami[1*] and Shri Kant[2]
[1*]Assistant Professor, Delhi Technical Campus, Greater Noida, India
[2]Student, Delhi Technical Campus, Greater Noida, India

ABSTRACT
Healing is the process of re-establishing harmony within the organism. Illness implies a loss of this balance and the need for reintegration with the body's natural ability to heal and regenerate. The human body has ability to heal when put in healthy and positive environment. According to the World Health Organization (WHO), the Healing environment is defined as "an integrated system of human and physical factors exercising a significant effect on health, considered not only the absence of disease but as a complete physical, mental and social state". The goal of this study was to determine the architectural elements that will be required to provide a comfortable and soothing atmosphere for patients. The goal was to find these traits by undertaking extensive research on healing theory in relation to architecture in order to develop a critical and analytical knowledge of these difficulties.

Keywords: Healing, Healthcare, Environment, Patient Stress relief.

1. INTRODUCTION
In 2004, Samueli Institute, proposed healing-focused framework for delivering care and coined the term optimal healing environments (OHE). An OHE stimulates patient healing by addressing the social, psychological, physical, spiritual, and behavioral components of healthcare, enabling the person's innate capacity to heal [1].

The OHE framework, as shown in figure 1 is composed of 4 integrated environments that reinforce each other by acting synergistically. Each environment is applicable on a personal level to the important relationships in our lives, to the organizations and physical environments where we work, heal and receive healthcare[2]. Refer figure 9.1

Figure 9.1 Optical Healing Environment Framework
(***Source:*** OHE website https://www.ohe.org/about-ohe/)

1.1 Healing Environment or Healing Architecture
Healing architecture for healthcare facilities describes a physical setting that supports patients and families through the stresses that develop as a result of illness, hospitalization, medical visits and the healing process. The concept implies that the physical healthcare environment can make a difference in how quickly patients recover or adapt to specific conditions [3].

Architecture and the built environment have the potential to influence the individual's well-being. Few architects such as, Architects Christopher Day (Day, 2004) and Carol Venolia identified and analyzed healing elements and how some elements can be altered in order to bring mental and physical therapy into the built form. These elements include light, color, material, texture and vegetation [4].

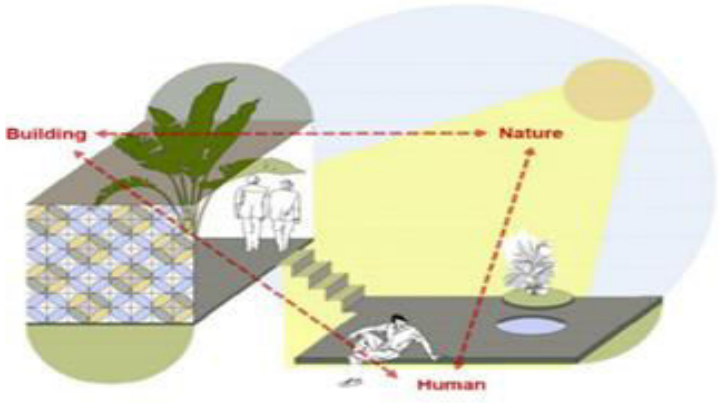


Figure 9.2 Interrelation Between Human, Nature and Building.
(***Source:*** Google images)

1.2 Goal of Healing Architecture

- Healing spaces design in such a way that they eliminate noise, poor air quality, lack of privacy, lack of sunlight.
- Introduce natural elements like outdoor views, interior gardens, water elements and natural sunlight.
- Giving the patient right to choose what they want, such as to get socialize or not, control brightness of the light, what type of music they want to listen, get privacy.

2. LITERATURE STUDY

Literature study provide an overview of ideas and significant literature of different researchers. It gives understanding of how the natural environment affect human physically, mentally in their process of healing.

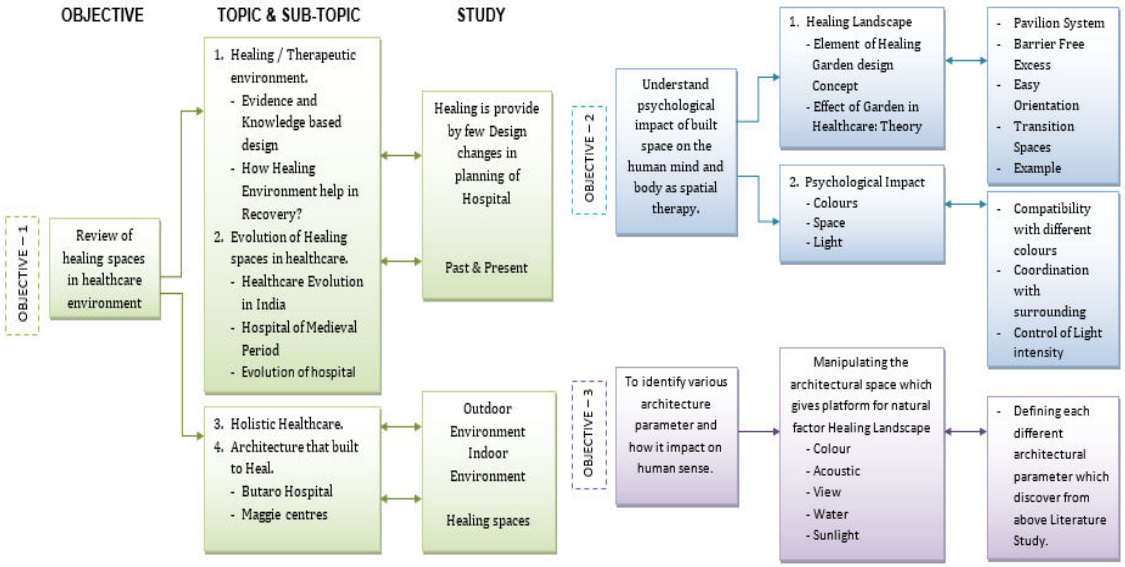


Figure 9.3 Detailed flow chart of literature study.

3. METHODOLOGY

These healing spaces in healthcare, helps in speedy recovery from illness and reduce the stay time in hospital, rehabs, dispensaries and NGOs and it also reduce stress level in patients, their relatives and health worker staff. Healing spaces also imparts positivity in healthcare workers by which they work productively without stress [5].

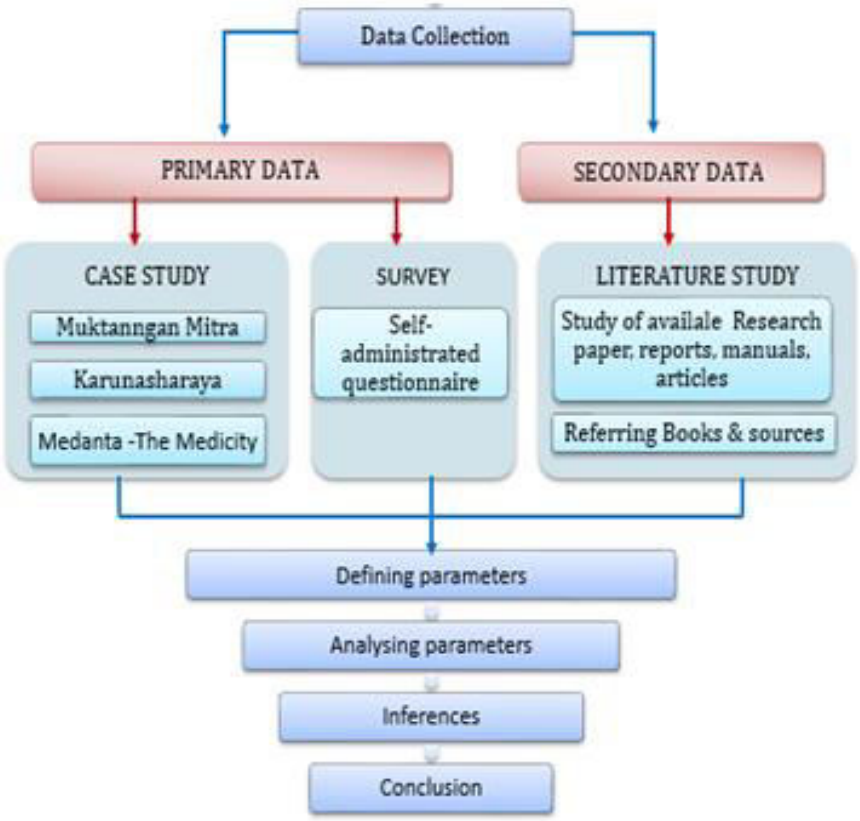


Figure 9.4 Detailed methodology chart.

4. CASE STUDY

4.1 Muktangan Mitra, Pune

Location – On Alandi road behind the RTO about 6km from Pune station.

Architect – Shirish Beri and Associates

A building which having therapeutic values and it helps in process of healing for Drug Addiction. This design having the transparency by which it expresses the freedom and increase physical and visual interaction. Visual connection with nature is established from the cut-outs, the terraced balconies and the sitting encourage the patient to interact and connect with nature [6].

Façade of this building comprises off transparent welcoming entrances. The exterior wall of the building having Stone rubble masonry. Building is surrounded by large trees and outdoor sitting for patients, their relatives and staff. Landscaping is done by providing raised planters and flower beds, as shown in figure 9.5 [7].

There is a small arranged open-air theatre of 150 seating, inhales light and ventilation in structure, it ties the different functions together, making a feeling of space. It is utilized as cooperation space and act as a center point.

Figure 9.5 Entrance Gate
(***Source:*** Shirish Beri and Associates https://shirishberi.com/)

Passageway have abundant measure of light and ventilation and visual availability with open area theatre. General ward balconies open into Amphitheatre, giving visual connection. Clearstory windows in the meditation hall give light inside from top opening.

Figure 9.6 Amphitheatre
(***Source:*** Shirish Beri and Associates https://shirishberi.com/)

3.2 Karunashraya, Home of Terminally Ill Patients, Bangalore
Location- Varthur Main Road, Kundalahalli Gate, Marathahalli, Bangalore.

Architect - Mindspace Architects

The center is design with Healing as the central concept. It is a place with lush greenery, bird's songs and peace, in the middle of metropolitan city. It was an attempt to create a serene environment with quality care, irrespective of caste creed or color, for terminally ill cancer patients [8]. The word "serene" acquires a new meaning here, that every corner is designed to stimulate calmness and peace in one's inner self.

This was achieved through introducing water bodies, greenery which enhance the feeling of close to the nature. Outside wall cladding done by granite stone, as shown in figure 7 [9]. There is a proper ventilation and penetration of natural light into the buildings. The patients get relax from the view of greenery in one side and water on another side of their wards. There is a courtyard between the wards which act as a transition space, as shown in figure 8.

Façade of the building is elegantly design with stone structure, creepers and flowering plants. In landscape a lot of huge trees is used as a voice barrier. There is sitting and relaxation areas for patients, visitors and staffs. The all-around ambiance is kept simple and green without any loud color [10]. Settle color combination are used throughout the building which provide psychological comfort to the patient.

Figure 9.7 Water Body for Micro Climate
(***Source:*** Mindspace Architects https://mindspacearchitects.com/)

Figure 9.8 Open Courtyard Accessible for Patient.
(***Source:*** Mindspace Architects https://mindspacearchitects.com/)

3.3 MEDANTA – THE MEDICITY

Location CH Baktawar Singh Road, Medicity, Islampur Colony, Guru gram, Haryana

Architect – ARCOP Architectural Firm

The design philosophy behind this Hospital to provide Health and mental well-being of the patient along with their relative and working staff of hospital by providing integrated, innovative and compassionate care. Creating spaces which help in provide privacy, rejuvenation, choice, feel and experience the nature, interaction, collaboration and communicate with others [11].

The architecture of this hospital considering the healing source factors like daylight, nature views and optical privacy that create the healing environment that effect and support the patients in the process of psychological and physical healing [12].

Building has large Glass window façade which help in the penetration of sunlight deep inside the building and also provide outside view. At the heart of Medanta are two 21-foot-high hand carved sand stone Trees of Life, mannat (wish, prayer) trees. These stand in the public lobby. There are two bowls that have the message inlaid in quartz – Har ek jaan anmol (Each life is precious). Proper space like canteen area is provide for both patient relative and staff. Around the building there is garden and open courtyard which bringing natural light and viewing windows into every patient space possible.

Figure 9.9 Views of Open Garden & Building
(***Source:*** ARCOP Architectural Firm http://arcop.co.in/)

4. COMPARATIVE ANALYSIS

Following image shows the comparative table of the study- refer figure 9.10.

CASE STUDY & PARAMETER	CASE STUDY 1 MUKTANGUN MITRA	CASE STUDY 2 KARUNASHARAYA HOSPICE	CASE STUDY 3 MEDANTA MEDICITY	ARCHITECTURAL INFERENCES
COLOUR	Use of light tone colours like white, light skin colour and sky blue. 	Mostly both the interior & exterior cladded with dark grayish stone. Use of light colours.  	Use of light tone colours along with colorful furniture and large ceiling height.  	• Colors inherent significance in architecture and have a strong creative identity. • Colors are expressive and are lovely to look at and touch. • Colors are frequently brilliant, painted in numerous coats, and stained over, leaving a shimmering or imprint on the surfaces.
ACOUSTIC	Wards and Consultant room are at back side or away from the road side and surrounded by large evergreen trees, which block the noise of traffic. 	There are the proper buffer area of green and use of multiple courtyard and water features.  	There are three large garden which act as a buffer.  	• Planning of a building should involve consideration of acoustical impacts to achieve a productive environment. • Acoustic separation of activity zones from zones requiring peace and quiet should be considered.

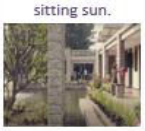
CASE STUDY & PARAMETER	CASE STUDY 1 MUKTANGUN MITRA	CASE STUDY 2 KARUNASHARAYA HOSPICE	CASE STUDY 3 MEDANTA - THE MEDICITY	ARCHITECTURAL INFERENCES
LANDSCAPE & VIEW	The building is designed in a way that all rooms of receive view of water feature & gardens. 	Getting the spectacular views of water features and gardens. 	Terrace healing garden view from every patients room windows 	• Design for movement and exercise, brings physical and emotional relief. • Paths for walking, garden visible from corridors used for exercise, wards in view of the garden
WATER	There is no water feature in Muktangan Mitra.	Large expanse of water, forms major feature, around which built form orient itself. Capture feelings of tranquility and a sense of calm. 	There is no water feature in Medanta – The Medicity.	• Water promotes healing and prosperity because it is positioned in the right direction in respect to the site and the structure. • Moving water is a powerful image of triumphing over adversity.
SUNLIGHT	Small enclosed landscaped Amphitheatre bring direct sunlight and large open skylight dome also there. 	Oriented in such a way the patients in ways get blessed with the rising and morning sun but not by the sitting sun. 	Orientation of blg. Done in such enclosed green area in between is having shaded area. Interior space of bedroom, get ample amount of daylight. 	• Sun exposure is one of the environmental elements that designers employ to stimulate the healing process. • The concept that adequate light is required to help weak bodies heal is not a new one.

Figure 9.10 Comparative table of Study.
(***Source:*** Author)

5. DESIGN RECOMMENDATIONS

On the basis of case studies, literature investigations, analysis, and critical observation, the physical components influencing the healing environment in health care facilities are identified. The users' well-being might be influenced by subsequent design considerations [13].

- **Welcoming Entrance**
- **Qualitative Daylighting**
- **Privacy**
- **Open Space**
- **Biophillic Approach**
- **Space for Interaction**
- **Creating Positive Distraction**
- **Waterbody**
- **Calm and Quiet Environment**
- **Colour**
- **Sense of Freedom**
- **Building Orientation**
- **Space for Family and Relatives**

6. IMPLICATIONS

For the construction or designing of any healthcare building weather it is hospital, dispensary, clinic, rehabilitation center, etc. all has monotonous form of design [14]. These building were design only to fulfill the function for which that was built. But actually, they fulfill main requirement of healing, it a big question?

As we all know for design a healthcare a lot of guidelines and permission were taken from different authorities and government organizations like Central Drugs Standard Control Organization, National Accreditation Board for Hospitals & Healthcare Providers, Ministry of Health and Family Welfare, National Health Service, Indian Council of Medical Research, AIIMS New Delhi, etc [15]. All these organizations graded the hospital on their infrastructure, how much bedded hospital it is, which type of treatment they provide [16].

But there is no organization which focus on the how much and what kind of healing space is there in hospital or not [17]. No organization graded the healthcare center on the basis how much the building help in natural (physical as well as mental) heal to the patient as well as their families and healthcare working staff.

In COVID-19 we all see how patients were mentally retarded from the quarantine ward in Covid care units. There is no distraction for patients from their pain [18]. So. In future there should be a proper jury or organization which graded the healthcare building whether it is small clinic or large multi super specialist hospital on the basis that how much that building healing properties. They graded the building from low to best. It should also be added in the guidelines and become a prominent factor for opening any new healthcare building [19].

New policies and By-laws should be made which incorporate the importance of healing places in healthcare because Healing architecture for healthcare facilities describes a physical setting that supports patients and families through the stresses that develop as a result of illness, hospitalization, medical visits and the healing process [20].

7. CONCLUSION

The study findings give a complete review of the literature on the topic addressed in this work. The goal of this study was to determine the architectural elements that will be required to provide a comfortable and soothing atmosphere for patients. The goal was to find these traits by undertaking extensive research on healing theory in relation to architecture in order to develop a critical and analytical knowledge of these difficulties.

Firstly, architects should diminish the institutional ambience during the design process and produce a salutogenic design that will alter the pathogenic attitude. As far as I can tell, the patient can use different portions of the environment, both interior and exterior, relying on where they are in the rehabilitation process. Outdoor places are always filled with luscious greenery and the soothing sound of running water to soothe their tension. Indoors, the sunlight enhances healing and ventilation, providing a high level of conformability for the patient.

Furthermore, the power of architecture to treat mental and physical sickness may be investigated using various planning characteristics and aspects that can aid healing. Without jeopardizing their needs, all patients should be able to spend time outside in a pleasant setting. The organic process of constructing architecture almost seems like we develop our own abstract thoughts of what we want a place to be, and we build architecture to be a part of the real world through particular images from memory. Healing via art appears to be a process of reflection, self-development, and self-discovery. This study yielded a key design aim that might have been crucial in building space-making techniques for my healing building in healthcare design.

Various aspects of architecture have been examined and evaluated throughout this dissertation. These elements must be combined to produce a healing space or atmosphere in a healthcare facility that aids in the reduction of stress and anxiety. The visual, functional, physical, sensory, and natural features all help patients relate to their surroundings. In addition to the ideas & theories as presented in Literature reviews and Case studies, these attributes could be utilized in the design phase.

The hypothesis that I make “The Healing space of healthcare center, not only improve physical and mental health of patients, but also provide positive impact on patient’s relatives and hospital staffs.”

It is correct that providing healing places in healthcare by modifying architectural space that provides a platform for natural components is a good idea (light, sound, views etc.). This therapeutic place aids in the reduction of worry and tension, as well as aiding the healing process.

REFERENCES

1. Jaja Thaddeus, Akuneho (2021). “Healing Architecture for Hospital”. Global Scientific Journal, 1321-1326.
2. Ananth, S. (2008). “Healing Environment: The natural next step”. Explore, 273-274.
3. Baldwin, E. (2016). The Architecture of Healing: 12 Maggie centers. Architizer, 1-10.
4. Bryan R Lawson (2010) “Healing Architecture”. Art & Health, 95-108.
5. Benedetti, F. (2001). “Morning sunlight reduces length of hospitalizations in bipolar depression”. Journal of Defective disorders, 1-15.
6. Chrysikou, E. (2014). “Architecture for psychiatric environments and therapeutic spaces”. Amsterdam: IOSPress, 1-10.
7. Davis, C. (2014). “Shining light on what natural light does for your body”. Focus on Design, 1-5.

8. Day, C. (2004). “Place of the Soul: Architecture and Environmental Design as healing art”. Taylor & Francis.
9. Francis, M. a. (1990). “The Meaning of Garden”. The MIT Press.
10. Gazali R., A. M. (2012). “Assessment of Healing Environment in Paediatric Wards”. Procedia - Social and Behavioral Sciences, 149-159.
11. Holmes, L. (2000). “11 scents that can do wonders for your living”. The Huffington Post.
12. Saloni Singh, Mohammed Sabahat, Juwairia Qamrudiin (2021). “The Impact of Architecture in the Process of Healing & Well-Being”, International Journal for Research in Applied Science & Engineering Technology,202-222.
13. Jonas WB, C. R. (2014). “Salutogenesis: The defining concept for a new healthcare system”. Global AdvHealth Med., 82-91.
14. Joye. (2007). “Our surroundings influence not only the way we think but our intellectual development”. Research daily.
15. Kuller R., B. S. (2006). “The impact of light and colour on psychological mood: a cross-cultural study of indoor work environments”. Ergonomics, 1496-1507.
16. Levy, J. M. (2007). “Ceiling Height Can Affect How A Person Thinks, Feels And Acts”. Science daily. 1-10.
17. Melinda Ratini, D. M. (2020). “What Is Holistic Medicine?” Research Gate thesis, 1-10.
18. Ottosson. (2007). “The Importance of Nature in Coping, Creating increased understanding of the importanceof pure experiences of nature to human health”. Swedish University of Agricultural Sciences, 20-28.
19. Psychologists. (2009). “How the colors of interior walls influence the imagination”. British Columbia.
20. Robert N., G. M. (2005). “The efficiency of light therapy in the treatment of mood disorders. A review and meta-analysis of the evidence”. American Journal of Psychiatry.

Chapter 10

HEALTHCARE CHILDREN'S HOSPITAL DESIGN: THE ROLE OF ARCHITECTURE IN DESIGNING A SPECIALIZED HEALTHCARE CENTER FOR CHILDREN

Kirti Sharma[1*] and Divya Saxena[2]
[1]Associate Professor, Delhi Technical Campus, Greater Noida, India
[2]Student, Delhi Technical Campus, Greater Noida, India

ABSTRACT
Children are more social and are always observing and absorbing their day-to-day interactions, this means that the life and environment around them reflect upon them in molding their personalities. So, the space surrounding them as a patient does not just serve one purpose but molds their overall well-being and growth. Children-centered hospitals are designed with specific features and details in order to reach optimal support and care for infants to adolescents, in a specific environment. In such healthcare centers, doctors from multidisciplinary teams such as pediatricians, surgeons, intensive care specialists, and anesthetizes among others come together to provide their services to the kids in need. This chapter reviews the different healthcare children's hospitals to gave the readers an understanding of the psychology of children in the built environment, relationship of children with the interiors and design aspects of the hospital, how a safe and secure space can be built within a children's hospital etc.

Keywords: Children, Hospice design, healing architecture, pediatric care.

1. INTRODUCTION
The building design of a healthcare facility is made to be categorized, but at the same time, it should also encourage interaction to make the environment more supportive for the social children. Despite the benefits of a human-centered design, hospitals can overlook the healing process for a patient. The building design plays an essential role in the healing process and time of a patient by proving a therapeutic hospital environment for young and mostly confused patients [1]. This building design also proves to cater to challenges like the COVID-19 national crisis. Hospitals for children besides just being a building where sick children are admitted, also serve the unique role of giving primary care for a child's mental health and in-school services which can help them ease their journey [2]. Therefore, a hospital for them should give a homely feel, where they can be safe and not feel alienated.

The need to study the design of a children's hospital is crucial due to the design reasons –

- Children are not like adults and need special care and treatment when it comes to their health.
- The need for a specialized hospital for pediatric care is imperative.
- Designing a children's hospital must have a different approach than a general hospital.
- A children's hospital is needed to provide mental comfort not only for the children (patients) but also for the parents and family members.
- Architecture affects children differently, the quality and quantity of space both affect the behavior of a child – especially when it comes to a place like a hospital which most children are fearful of.

The main aim of this work is to research how architecture can come into play in creating a specialized children-centered environment. To study various design possibilities to be able to plan a pediatric hospital that has a more children-centered environment and also facilities that give both the children and parent a chance to ease into their problem and relieve their stress.

Some of the specific objectives are:

- To identify the aspects and key features of a children's hospital design.
- To understand how architecture impacts the lives of young patients
- To learn new trends in healthcare architecture for children in order to design better
- Understanding the methods of merging play within a hospice
- Designing safe and carefree healthcare for children.

1.1 Hypothesis

When we design a more child-centered healthcare environment via the use of architecture, we make it a pleasant experience not just for young patients but also for the families. \

1.1.1 Limitations

- Data collected is from a secondary source
- Case studies will be limited to online data and analysis due to the limited time period.
- Since this a new design field in India there is limited documented information and insufficient material.

2. LITERATURE STUDIES

2.1 Study of Children's Behavior in Pediatric Hospitals: A Design Perspective

- **Objective** –To understand the behavioral response of children towards the physical environment. All spaces in a hospital have a strong association with activities carried out in the areas and have an effect on the patients using the space.

2.1.1 Relationship between Comforting and Transitional Spaces

The visual or physical access to the various surrounding environments, both natural and man-made, contributed to comfort in children by distracting them and creating a sense of play [3]. The large size of spaces attracts children more and hence makes them more active – like unobstructed spaces, large lush green courtyards, terraces, etc. On the other hand, cozy & warm spaces led to physically comforting.

Figure 10.1 Images representing comfort and distraction by different strategies in various transitional spaces – (a) Courtyard (b) Atrium,
(***Source:*** google images)

2.1.2 Relationships between Comforting and Circulation Spaces

The cozy and safe enclosure of corridors with narrow and long feelings solace the children and actively engage them. Whereas the complexity & variety of the space donates to the comfort of a complaint investigation. The visual emphasis of the content with familiarity contributes to the comforting by creating a focus on asked objects, while visual emphasis with riddle contributes to the comforting by distraction [4].

Figure 10.2 Images representing various comforting activities by different strategies.
(***Source:*** google images)

7.1.3 Relationships between Comforting and Activity Spaces

Comforting by play and extra spaces, scale, variety, and, characteristics of the play, hearing & seeing the space and, stretches the area to contribute to the comforting of children by active engagement. The visual emphasis of the space & bright colors of the surrounding objects as well as the spaces contribute to assure distraction [5]. It can be noted that the variety and physical characteristics of the playing outfit (size, shape, color, material, homestretches, etc.), visibility of the space, scale & position of the space, auricular and visual link of the space, and safety are the important factors contributing to the comforting of children. Refer figure 10.3.

Figure 10.3 Views showing comforting by different strategies play areas and undesignated spaces.
(***Source:*** Google images)

2.2 Integrating an Element of Play in Healthcare Environments for Children

2.2.1 Understanding the Methods of Merging play within a Hospice.

Providing top-notch medical care is the main priority of any hospital, but along with the medical facilities, attention should also be paid to the aesthetics and design element keeping in mind the

user. A child-friendly, pleasant and welcoming environment may not cure the illness of a child, but via the use of, play we can benefit the patient in many other ways as its underlying component can work wonders for the healing process of patients. Being hospitalized brings many stressful and worrying thoughts into the psyche of the children, which in turn causes a child to be more worried and anxious and ultimately adds to their sickness. Creating positive and playful experiences in the hospital environment can transform an otherwise stressful and anxiety-ridden stay for children to an entertaining one. According to the authors, a children's hospital that incorporates Play can lead to a positive mindset in young patients, while aiding and quickening the healing process [6].

2.3 Dynamics of Architectural and Urban Planning Hospital Systems Evolution

2.3.1 To Identify the Aspects and Key Features of a Children's Hospital Design

When designing new hospital buildings, the main challenges involve the need to produce a blueprint that provides scenarios for additional growth (expansion of all or some of the constituent components, altering the operational aim of some elements) [7]. The main issues that need to be answered entail finding fashions for the sustainable development of the medical structure, as well as the need to invoke a fabric that has the internal prospect to induce a remedial ambiance. The way out of this situation can be timely, phased updating of the structure and association of the hospital building, monitoring of promising tasks, and the quest for optimal ways to administer them [8]. even so, the primary transfer and application of foreign experience of these transformations are impossible in each country, there are a number of positive and negative aspects to furnishing hospital services. There's no ideal model, the same way of organizing a medical center network cannot be used in its "pure form"- adaptation to the regional characteristics, and social, economic, and political capabilities of each particular state is necessary, as well as considering demographic indicators and the dynamics of progressive ailments. With all the ultramodern world's variety of ways to organize hospital systems, when designing, it's worth considering the general trends the enlargement of medical structures, the configuration of complexes; emphasis on the intensity of treatment, the use of day hospitals; individualization of design opinions, rejection of stereotypical hospital forms; the formation of an aesthetic space with rehabilitation capability; ecological approach and harmony with the context.

2.4 Safe Healthcare Facilities for Children and Adolescents

2.4.1 Designing a Safe and Carefree Healthcare Center for Children

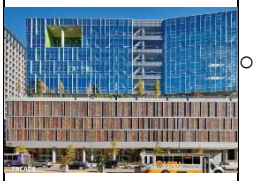
The escalating need for health services is an actuality. Therefore, hospital design is a sizable branch of prevailing architectural trends. Children's healthcare complexes are very unique, complicated, and necessary. They're a challenge for every architect due to the diversity of their tasks. A technical healthcare facility for children can offer more thoroughly safe medical care to this unique group of patients. Contemporary children's hospitals are grounded on the best interest of a hospitalized child; certain principles and criteria are applied to the specific issue of safety and health advancement for children and adolescents in and by hospitals. Architecture, 13 technologies, psychology, and ecology are each involved in the healing terrain of today's healthcare complexes. Specialists from different epistemological fields are cooperating in order to eliminate the children's fears of medical canter visits and turn that into a safe and useful experience. Design details have an impact on the quality and value of care. Effective and flexible design provides further comfort for patients and their family members. In contemporary architecture, there are numerous exemplifications that offer safety and security during the children's hospitalization process.

3. CONCLUSION

After vigorously studying various papers related to my research topic, and analyzing the hospital buildings via case studies certain conclusions were made and concepts were set straight. Based on various aspects the papers for literature review have been selected that gave the understanding of

1. The psychology of children in the built environment
2. Relationship of children with the interiors and design aspects of the hospital
3. How a safe and secure space can be built within a children's hospital
4. Dynamics of a children's hospital, among others. The thorough research and analysis have led to the following conclusions and inferences based on certain formulated parameters. 1

Table 10.1 Comparative chart

Parameter	Inferences
1. Façade 	○ If planning a glass façade - it should be decorated with random patterns of repetitive elements in order to attract the young ones and also to create a shimmering effect and fluid reflections when struck by the sun (hence also incorporating the nature). ○ The façade can be continuous and smooth but at the same time also vibrant and transparent with color and depth to its surface. The façade can comprise of plain and sober colors with a row of contrasting ones giving an exclusive effect to the building exteriors. ○ The exterior and interiors of the building complement each other and should be a viewpoint easy to be located and navigate to ○ The exterior can be made to focus on energy efficiency while incorporating an interesting and amusing design color palette ○ the façade design should follow function as well as a form to make the most of the aesthetics and keep the building efficient as well
2. Landscaping  	○ The main entrance should display the landscaping which it can go hand in hand with the gallery/café and retail spaces created at the ground floor level that in turn enrichens the place and makes it livelier. ○ Some seating/eating spaces along with open green areas should be designed in the front of the hospital building creating a lively ambiance ○ Trees can be planted along the boundary i.e. aligned with the roads to filter away the pollution and noise coming towards the building ○ Landscaping in the building interiors can also be done in order to bring in the nature to the bedridden patients. E.g. A sky lobby leading to a rooftop terrace garden – this space will bring together the sky, water, and forest and also offer an excellent view. ○ On the site level much percentage of softscape regions is to be planned in order to give the patients plenty of areas to laze around and play outside without getting hurt any further. An Atrium can be planned indoors that should include the necessary amount of landscaping indoors - the atrium design establishes the visual integration of all parts into the total entity of hospital.

3. Design 	o The design of the building should be inspired by elementschildren can relate to or are familiar with. e.g.– natural elements - water, which is believed to have manyintrinsic and symbolic characteristics that interpret a supportive and healing element. Water can gain any shape and color and thus can be abstracted
	and interpreted in pattern, color,texture, and form. o The hospital planning should be done in a way that it incorporates all essential services required for the functioning of a hospital. o Efficient planning of the services leads to the energy theme that reflects the interiors and the use of posters in patient rooms o The building design to optimize flexibility and efficiency. The design allows for future horizontal and verticalexpansions as well. o The patient rooms can be aligned along the atrium corridor and so that the children get to experience the activities being carried out in the atrium on a day-to-day basis, which in turn helps distract them from their pain and the boredom of being in thehospital room. o The atrium planning should be done after a rigorous amount of investigation to achieve the mosteffective building form to cater to the needs of the children being admitted to the hospital. o The design of the hospital givesa more striking and authentic tone: mature yet lively architecture fit for the youngsters, an enriching and fresh interior atmosphere, and a site design that celebrates the role nature can play in thehealing process.

REFERENCES

1. Bulakh, I., Chala, O., & Divak, V. (2020). “Dynamics of architectural and urban planning hospital systems evolution”, Civil Engineering and Architecture 8(4):586-598
2. Vavili, F., & Kyrkou, A. (2010). Safe Healthcare Facilities for Children and Adolescents” Architecture, Interior Design (Architecture).1-5.
3. Suomi, S.J. and Harlow, H.F. (1971). “Monkeys without play”. Bruner, 1-10
4. K. eds. (1976) “Play: Its role in development and evolution.”, Basic Books.
5. Noble, E. (1967). “Play and the Sick Child”. Faber and Faber Limited.
6. Filippazzi, G. (2009) “Also Walls Speak..., Culture for The Future of Healthcare Architecture”, Proceedings of 28th International Public Health Seminar, edited by Prof.Romano Del Nord. Alinea editrice, Firenze.
7. Pinhao, C. (2016) “Children’s Hospitals- The role of architecture in children’s recovery and development”. Master Thesis in Architecture.20-35
8. Csikszentimihalyi, (1997). “Creativity: Flow and the Psychology of Discovery and Invention”.

Chapter 11

SCOPE OF PREFABRICATED CONSTRUCTION FOR SUSTAINABLE DESIGN

Mohd Parvez Alam[1*] and M Shadab Alam[2]
[1*]Assistant Professor, Delhi Technical Campus, Greater Noida, India
[2]Student, Delhi Technical Campus, Greater Noida, India

ABSTRACT

Prefabrication is already widely used in the construction industry across the globe. Two of the best examples are the Sydney Opera House and the Burj Khalifa in Dubai. Prefabricated buildings only make up 1% of all real estate in India, where prefabrication and other modular technologies are still in their infancy. The fundamental cause of this is because prefabrication as a technique still struggles with mindset issues in India, where people are reluctant to adopt prefabrication in both new and ongoing projects. This creates a divide between current construction technologies used around the world and old construction methods used in India, which could ultimately hinder the development of the nation. The research aims to answer questions related to prefabrication construction as an alternative for sustainable buildings on a global scale. The subject of this paper is to explore the opportunities of prefabrication construction thus making it the ultimate fabric of sustainable and fast construction, thus helping the mankind for a better world.

Keywords: Prefabrication, Modularization, Sustainable, Assembly.

1. INTRODUCTION

Prefabrication is a broad term that refers to a variety of systems and techniques. Structural, architectural, and service description can all be incorporated. It is used by many industry units. Though, it is predominantly helpful for contractors in the construction sector because it shortens project timeframes and enables faster project completion. Environmental awareness and technical advancement have increased exponentially in recent years. As a result, many individuals are now interested in building structures that are environmentally friendly and sustainable while still allowing them to live comfortably. This leads us to modern prefab construction solutions, which provide us with construction that is environmentally friendly, cost-effective, and extremely energy-efficient. The prefabrication business has completely transformed the construction industry [1].

Sustainability allows for a comprehensive solution to environmental and societal crises by establishing the essential links between nature, culture, economy, politics, and technology. Prefabricated elements offer environmentally friendly, energy-efficient, and cost-effective building solutions. Prefabricated modular constructions are becoming more common [2].

Customers are beginning to examine the effects of project sustainability during construction, operation, and maintenance. Today's world is attempting to meet forthcoming issues such as conserving natural resources, increasing the use of recycled materials, environmental deterioration, and total construction costs, among others. All of this can be accomplished by enforcing current sustainability theories and altering sustainability elements. The outcome of this conflict, which can be seen in both industrialized and developing countries, is intimately tied to economic progress pressures. The economic impact of new prefabricated and construction technologies should be considered in the framework for sustainable infrastructure design [3].

Precast concrete panels are an example of prefabricated components that can be used to make walls and slabs in a structure instead of hollow blocks. Instead of creating concrete panels, on-

site plastering would be necessary after building up a mould, pouring concrete into it, and waiting for the cement to cure. One can order unit off-site for a softer finish and a simpler solution. Furthermore, adopting prefabricated pieces would reduce the amount of labor required for project operations. In this context, the subject of this paper is to explore the opportunities of prefabrication construction thus making it the ultimate fabric of sustainable and fast construction, thus helping the mankind for a better world [3].

2. WHY PREFABRICATION?

Finding strong relations to state that prefabrication can be a sustainable practice as compared to traditional construction techniques. In broad aspect, will prefabrication be termed sustainable?

- Studying on Prefabrication construction for high rise homes and its applications towards a sustainability approach
- Finding data which gives solid grounds to term prefabrication construction as sustainable
- Suggesting efficient strategies and area of improvement in present prefabrication industry

The research aims to answer questions related to prefabrication construction as an alternative for sustainable buildings on a global scale. The subject of this paper is to explore the opportunities of prefabrication construction thus making it the ultimate fabric of sustainable and fast construction, thus helping the mankind for a better world [4-6].

Prefabrication industry is currently a more sustainable approach as compared to traditional methods and with increasing time, it is ready to adapt a more sustainable and quick approach in the future along with ease of technology integration

- Detail study of prefabrication construction along with its construction process, techniques and applications
- The advantages and disadvantages of prefabrication construction:
- Pros and cons of prefabrication with respect to traditional construction techniques.
- Prefabrication for high rise apartment buildings
- Area for improvement for prefabrication and new strategies implementing to enhance the performance
- Studying the environment footprint of prefabrication industry:
- Detail analysis of prefabrication industry and its effects on the environment.
- Adoption of prefabrication and overcoming the barriers for mass adoption.

3. LITERATURE STUDY

The literature reviews of the following topics will be given to show expertise with the subject and place the research within the context of existing knowledge.

a) Introduction to prefabrication

b) Prefabrication for high rise apartments:

c) Parameter analysis of prefab & traditional construction

d) Major sustainability components

e) area for improvement and new strategies implementation

f) Major stakeholder advantages for a collaborative ecosystem

g) Adoption of prefabrication

4. CASE STUDIES

4.1 Godrej Golf Links, Sector - 27, Greater Noida

It is 100-acre township project with 9 whole golf course & world class amenities along with luxurious, high rise, low rise, studio apartment and the suite. All villas and apartment is facing to golf course. Construction or development taking place in phase wise manner.

Fabricated structures are built by fabricating whole building component members such as beams, slabs, columns, and walls, and then delivering it to the construction site where they are fitted together, much like Lego blocks.

- Rather than bolted system they use sleeve and dowel system.
- Wall to wall connection is through hooks
- In column they use nibs/corbel (Haunches) for supporting beams
- Slabs are half constructed in factory (100mm) and the rest 50mm are covered with screed on site
- Foundation is made on site till stilt level
- Slabs are directly connected to the wall

Table 11.1 Sustainable parameters in Godrej Golf Links.

S. No	Sustainable Parameters	Gordrej Golf Links
1.	Safety	The workers safety is more because of adequate machines to handle the process and better supervision
2.	Cost	The construction cost by preassembled products which are made in bulk and is comparatively cheap
3.	Time	The construction time by pre manufactured elements and no curing time saves time
4.	Quality Control	Strict quality control because of a controlled and high surveillance manufacturing plants present on site
5.	Flexibility	Easy assemble and disassemble and moving materials to different place within the site is easy.
6.	Environment Impact	The components are produced in a controlled factory environment which is less harmful for environment. The extra material is recycled back to manufacturing plant.

4.2 Tamedia Office Building Zurich, Switzerland

The headquarters of the Swiss media firm Tamedia are being built on a 1,000m^2 plot in the centre of Zurich, within a bigger urban block where the group's present primary structures are. The building's location in the east of the block gives the site a unique opportunity to design a nearly 50-meter-long linear facade that faces the SIHL canal.

Structure's layout essentially corresponds to the footprint of the previous layout that will be obliterate, but now it maintains linkage with the adjacent buildings' facades and makes use of the maximum height permitted to maximize the usable office space on this side of the building block.

Structure has the total net area of 8,602 m^2, which can be increased by 1,518 m^2 to match the 2-story extension project on the roof of the neighboring building at 8th number of staufferquai street. The structure has 7 storeys over ground floor and 2 basement levels.

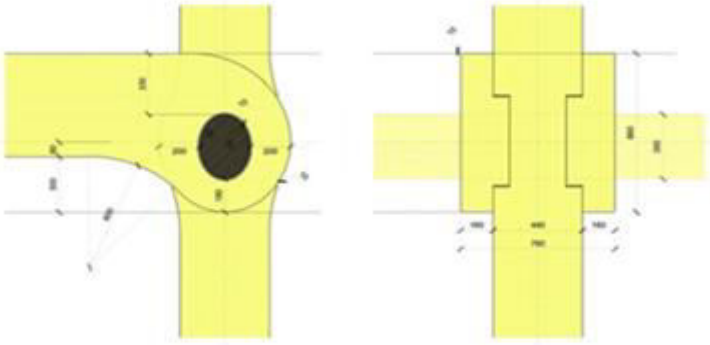


Figure 11.1 Layout Plan of Tamedia Office Building Zurich, Switzerland.
(***Source:*** Tamedia https://www.tamedia.ch/de/)

The project's most important innovation is, by far, the main structural system made of timber. The suggested timber construction is an inimitable approach to this sort of office building from a technical and environmental standpoint, and the verity that the structural elements are completely perceptible also offers the working area a highly unique character and high-quality spatiality.

- **Sustainability-** In addition to the contribution to sustainability selection of timber as the primary structural material, the mechanical arrangement has been developed such as to satisfy the highest standards in energy. The intermediate space serves as a thermal barrier and is also one of the open areas that will be heated and cooled by extraction air from the office space.
- **Architecture Point of View-** The key architectural components is the suggestion of structural system to be made completely of timber, from technical and environmental perspective, gives the structure a distinctive form from both inside and outside the building's walls and from the surrounding area of the city. A specific effort was prepared to accomplish low energy transmission levels that comply with the most modern and stringent SWISS energy consumption standards, and the building exterior is totally glazed in order to emphasize and convey this idea. In front of the city, the structure also highlights as an intermediate area all through the entire height of the east façade. In terms of overall energy usage, it serves as a thermal partition. It also creates a unique spatial experience with lounge space and correlates vertical links between the office stories. The balconies have the flexibility to be transformed into open-air terraces that increase the special linkage between the internal building and its nearby landscape, as well as the individuality of having a facade ease of a glass retractable window plan.

Figure 11.2 Tamedia Office Building Zurich, Switzerland.
(*Source:* Google Images**)**

4.3 Hotel Brooklyn, Leicester

The most recent development to Welford Road, the habitat of rugby union premiership team Leicester tigers, is a steel-framed hotel. The 1.7-acre site, where the hotel Brooklyn is being built, was formerly home to the Granby halls live music and entertainment complex. Marshall CDP is developing the £22 million project, and its construction arm, marshal construction, is serving as the project's main contractor. The hotel Brooklyn's 6 story building has 191 rooms for guest located on its top 4 floors, while at the ground floor level is primarily occupied by a car parking and retail spaces. The hotel's first floor will be located in the middle and have 3,300m2 of lobby, dining, and reception facilities in addition to a business centre.

A 28-meter-long, curving pedestrian bridge will connect this floor directly to the holland & barrett stand of the rugby stadium. It's interesting to note that caunton engineering, the steelwork contractor for the hotel project, also manufactured, provided, and installed the steel used to build this platform. Refer figure 11.3.

Figure 11. 3 Hotel Brooklyn, Leicester.
(***Source:*** Hotel Brooklyn https://hotelbrooklyn.co.uk/)

Prior to the start of the piling, work on this present plan got underway in 2020 early with a absolute borehole study of the site. Paul Stokes, the manager of Marshall Construction Contracts, explains: "Granby Halls had been destroyed a few years prior, and the location had most recently served as a parking lot. However, we lacked sufficient knowledge regarding the location of and whether or not there was a former basement beneath the site. We knew for sure thanks to the survey that there was no underground level, so we could start stacking. The 14-meter-deep piling foundations support the steel frame. With the exception of the bridge, the steel erection programme was finished by November 2020 after starting in March.

The general shape of the hotel is wedge-shaped, matching the contours of the property. The hotel's biggest area is located directly across from the rugby field and is formed by two wings of the building that project outward from the V-shaped structure's tip. Much of the space between the two wings is a sizable, covered gap that is located above the ground floor parking lot, which also includes back-of-house spaces. This will be an atrium with a first-floor reception and a roof that is a little higher than the surrounding wings.

The hotel's steelwork is built around a 7.72m regular column grid on either side of the atrium. This column spacing was selected because it was thought to be suitable for both the hotel rooms and facilities above and the bottom level parking lot. According to Mr. Phair, a few transfer structures to the parking bays had to be built without columns otherwise the steel would have

continued to pile up throughout the entire structure. On each wing of the hotel, the bedrooms are laid out in orderly blocks. On each floor, a central corridor divides two rows of rooms. Each corridor has service lines that are fitted within web holes in specially made beams that run down each corridor.

Caunton engineering is scheduled to return to the site this spring to complete the footbridge construction after finishing their primary steel programme. This will be put together on site, raised into position, and then disassembled into smaller pieces. The bridge will connect the new hotel with the current grandstand, although it will be a separate building supported by four columns. Putting it all together, andrea pinchent, chief executive officer of leicester tigers, says: "this is a crucial initiative to support the long-term ambition for our stadium and to contribute to the amenities in the city centre

4.4 The Soho Tower, Darwin Australia

The SOHO Tower is a 29-level modular structure located in Darwin, Australia's extreme north, a cyclonic area. The structure was intended to have a basement, eight stories made of traditional reinforced concrete, and then 21 levels of volumetric modular housing. The modules were built and completed in Ningbo, China, before being transferred to Darwin. Unlike other modular systems, this one utilised a concrete floor with concrete columns that were placed on-site into formworks inside the modules. Above level 7, a modular precast concrete system in the building's core provided the lateral stability system. Refer figure 11.4.

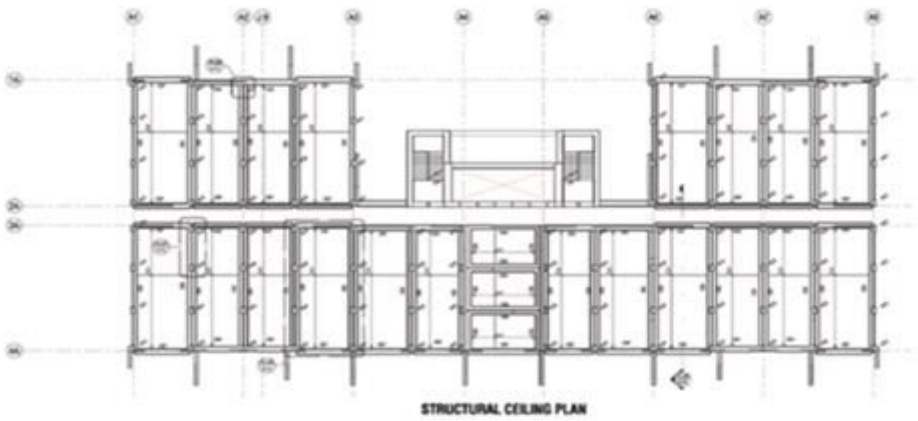


Figure 11. 4 Ceiling Plan of the Soho Tower, Darwin Australia.

The decision to "go modular" was influenced by a limited and expensive labour market. Initially a client request, the concrete floors turned out to have additional benefits.

The decision to study a volumetric modular alternative, with modules delivered complete with all finishes, woodwork, and fittings, was made due to the cost and lack of a qualified construction workforce. However, it was crucial that there be no significant alterations made to the building's design or exterior. This was a serious challenge.

- **Critical Design Parameters-** The previous section provided a summary of the geotechnical conditions. The design for shipping and handling was the other important criterion. The eight perimeter columns provided a vertical lift for the lifting system. Spreader beams were created and manufactured with the proper dynamic factors of 200% to meet this demand in the factory, on the dock, and on the job site. A large portion of the floor design was dictated by transportation on a 2.4-m wide truck without any extra structures, especially to prevent excessive deformations under dynamic loads. The modules were created to adhere to

Australian building regulations and codes. Its plumbing and other components, as well as steel, reinforcement, and concrete, were made in china.

- **Modular Design Options-** On a study to china and in local Australian markets, the first design alternatives that were given for consideration were steel framed. However, it was rare to find systems that could deliver 21 levels, made increasingly rarer by the fact that they had to follow a set configuration and withstand cyclonic wind loads.
- To accomplish the required fire rating and acoustic separation, specifics were designed. In a structure of this size with sprinklers installed, the applicable Australian standards required a 90 minute resistance for structural elements and 60 minutes for no structural fire barriers.
- The concrete floor was intended to be a slab, with cross beams and perimeter beams placed so that they would cross the perimeter columns. The cross beams helped to make the slab thinner and made sure the columns were securely fastened to the floor. Additionally, they eliminated the requirement for a spreader frame and allowed a 4.2 m wide module to be placed on a 2.4 m wide normal truck bed. After allowing for a 170% dynamic impact factor and taking into account the serviceability restrictions required to prevent cracking of the plasterboard, glazing, tiles, and joinery integrated into the finished modules, it was decided that truck transport of the modules was the critical load case for the slabs.
- A lightweight concrete mix using enlarged shale aggregate was specified in order to produce a concrete floor while maintaining realistic weight restrictions. A suggested density of 1600 kg/m cube was to be regulated by monitoring densities at the facility. To guarantee a steady supply of concrete and precise control over strength and density, a batch facility had been installed there. It was important to ensure rigidity, water tightness during transport, and proper fire and acoustic separation in the design of the modular ceiling structure. The circumference of the ceiling included a concrete ring beam. By doing this, it was made sure that all column load routes passed via concrete components.
- In order to support additional components and give rigidity at ceiling level for the lifting and stacking of modules, the concrete ring beam was further corbelled. Refer table 11.2.

Table 11.2 Sustainable parameters of Soho Towers.

S. NO	SUSTAINABLE PARAMETERS	SOHO TOWER
1.	SAFETY	The workers safety is more because of adequate machines to handle the process and better supervision
2.	COST	The construction cost by preassembled products which are made in bulk and is comparatively cheap
3.	TIME	The construction time by pre manufactured elements and no curing time saves time
4.	QUALITY CONTROL	Strict quality control because of a controlled and high surveillance manufacturing plants present on site
5.	FLEXIBILITY	Easy assemble and disassemble and moving materials to different place within the site is easy.
6.	ENVIRONMENT IMPACT	The components are produced in a controlled factory environment which is less harmful for environment. The extra material is recycled back to manufacturing plant.

5. CASE STUDY INFERENCE

Below table shows factorial comparison of different prefabrication technique buildings vs. traditional construction.

Table 11.3 Factorial comparison of different prefabrication technique buildings vs. traditional construction.

S.NO	Factors	Case Study 1	Case Study 2	Case Study 3	Case Study 4	Tradition Concrete Construction
1.	Percentage of industrialization	90%	60-90%	30%	10%	0%
2.	Durability	High	Medium	High	Medium	High
3.	Life cycle cost	Low	High	Medium	Medium	Low
4.	Strength	High	Low	High	Medium	Medium
5.	Automation possibility	High	Low	Medium	Low	Low
6.	Weight of module	High	Less	Less	Less	Less
7.	Scalability	Very high	Low	Medium	Low	Medium
8.	Speed of execution	Very high	High	Medium	Low	Medium

Below table shows technology comparison of modularization to conventional construction with parameters. Refer table 11. 4

Table 11.4 Technology comparison of modularization to conventional construction with parameters.

S. No	Parameter	3d Modular Precast	Conventional Construction
1.	Resource efficiency	Excellent(upto 60% less manpower)	Poor
2.	Time reduction	50% lesser	-
3.	Cost reduction	0.85x	1.00x
4.	Safety	Low risk to manpower(only 10% of work on site)	High risk of injury to manpower
5.	Sustainability	High(uses less and recyclable materials)	Low

6. CONCLUSION

The study compared case studies in prefabrication, including modular construction, steel construction, monolithic precast, EPS, and wood panel framing systems, with conventional construction methods. The following section of this paper reviewed four case studies from various countries. The first case study offers information about the actual state of prefabricated construction projects that have been implemented from the beginning. When compared to conventional building, the data clearly reflects the current situation and its efficiency. The second case study recommends building with EPS and timber frame panels. In addition to its revolutionary nature from a technological and environmental aspect, it demonstrates the viability of timber-built buildings with main structural systems wholly made and designed on timber.

The third case study discusses modular prefabrication for high rises, and the case study comes to the conclusion that it is the best technology for quick construction in areas with a labour and time shortage. The fourth case study discusses a steel-framed building, which is a type of prefabricated building. According to the study's findings, steel construction is extremely

effective at reusing and recycling materials, making it sustainable for nations that export significant amounts of metal waste.

Prefabrication can transform the construction business to some extent, if not completely. The research also provides convincing evidence for why using prefabrication is a sustainable strategy in contrast to conventional construction techniques. The comparison of these case studies reveals areas for improvement in achieving those goals. It is evident from the case study that using industrialization to produce these prefabricated modules can result in enormous savings of energy, resources, and money. By producing steel modules off-site, china had the fastest rate of building, as shown by the comparison of these case studies. This was probably brought on by extensive industrialization. To keep up with the rapidly changing environment, it is also vital to always provide room for the application of new methods, techniques, and construction materials.

However, additional study into the costs of each project can be conducted to complement this research due to the constraints of the research and applicability of data collection. Since the estimated project budget and actual cost were not made public, it was impossible to make a meaningful comparison between the projects. It was recognized during this investigation that case study 3 had the quickest project timeline. However, additional information like the costs, the number of employees, and the number of hours spent on the process might be assessed. Despite the fact that some case studies may have taken less time to complete than others, the project cost may have been more than twice as much. Therefore, in order to compare projects effectively, it is necessary to evaluate every component of each project in order to ascertain the actual project success.

REFERENCES

1. Shahzad, W.M, Mbachu, J. and Domingo, N. (2014). "Prefab content versus cost and time savings in construction projects: Aregression analysis‖". Proceedings of the 4th New Zealand Built Environment Research Symposium (NZBERS). 14 November. ISBN 2324-1829 (Online)
2. Stefan J. Weidemann, (1990), "Modular Pre-fabrication versus Conventional Construction as a Cost-Effective Alternative or the Construction of the Single Family Detached Housing in the Montreal Area‖", School of Architecture McGill University, Montreal.
3. BC Housing Manufactured Housing Association of BC Real Estate Institute of BC (2014). "Modular and Prefabricated Housing: Literature Scan of Ideas, Innovations, and Considerations to Improve Affordability, Efficiency, and Quality". BC Housing, MHABC, REIBC.1-80.
4. Svetlana Brzev (2010). "Precast Concrete Construction‖", British Columbia Institute of Technology, Canada Teresa GuevaraPerez, Architect, Venezuela.
5. Milovanovic et a (2020)." The Sustainable Prefabricated Wall Panel System Made of Recycled Aggregates". Croatia.
6. Hampson, K.D. & Brandon, P., (2004)." A Vision for Australia's Property and Construction Industry". Construction 2020

Chapter 12

ENHANCING THE PERFORMANCE OF CORPORATE ARCHITECTURE THROUGH SPACE PLANNING

[1]Saksham Gupta and [2]Jayneesh Kumar Mehta
[1]Assistant Professor, Delhi Technical Campus, Greater Noida, India
[2]Student, Delhi Technical Campus, Greater Noida, India

ABSTRACT
In this fast pace world, increasing competition and the struggle for survival in global markets had led to organizations re-examining ways in which the performance of their employees can be enhanced and resource-like space could be most efficiently used. Architecture details multiple layers of abstraction to form a complete and common view of information, guidance, and direction. Together these benefits form the guardrails for solutions—considering what's best for the organization—by adding guides and constraints to those solutions. The main focus of this research exploring ways to increase productivity by improving the quality of the physical environment i.e., the workplace which reduces stress, encourages engagement, and helps process better work output. Therefore, this research inquiries into understanding the performance of a space through design by taking parameters of spatial planning as lenses of study.

Keywords: Communication, collaboration, office productivity, office space, spatial planning and spatial performance

1. INTRODUCTION
Corporate architecture is designing spaces for the business community with the aim of meeting the needs of the organization and comforts of the occupants. Spatial planning is an in-depth analysis of relation between space and its users. It is an attempt to plan physical spaces in a way that social, economic, environmental as well as psychological aspects can be enhanced at their best to complement the space and its occupants [1].

2. RATIONALE
Why corporate architecture: The increased rate of globalization and development has in turn increased competition. It has led to organizations re-examining ways in which the performance of their employees can be improved and resources like space could be most effectively used. Due to this and technological advances, new ways of working have emerged. The main focus of the employers is to increase productivity by improving the quality of the planning which reduces stress, encourages engagement and helps process better work outputs [2].

Why spatial planning: This research inquiries into understanding the performance of a space through design by taking parameters of spatial planning as lenses to investigate. Since space is the medium facilitating work, spatial performance directly impacts workplace performance. Spatial planning is considered as a primary aspect of spatial performance since it structures the communication patterns between people and space and has a profound impact on how people interact. Therefore, this research attempts to understand the qualitative aspects influencing spatial performance based on defined parameters as well as how well the space supports communication and the correspondence between factors of spatial organization and concepts of human factors [3].

3. LITERATURE STUDY

3.1. Office Space:

The office environment is characterized as an environment where people connect, collaborate, innovate, create and document information [4]. In all, it is an ecosystem that fosters innovation, brings out the best in an individual through various means to foster business.

3.2. Spatial Planning of an Office:

Spatial planning is the first step considered while designing an office space. There are 3 Spatial Planning Through Implication of Organizational Principles: Since an office is a system of interrelated activities and functions, while planning a space it is essential to focus on how spaces are related to each other[5]. This organizes the form and order in the office. Organizational principles also lay a framework ofz specific communication Patterns that are envisioned in the space. Refer figures 12.1& 12.2.

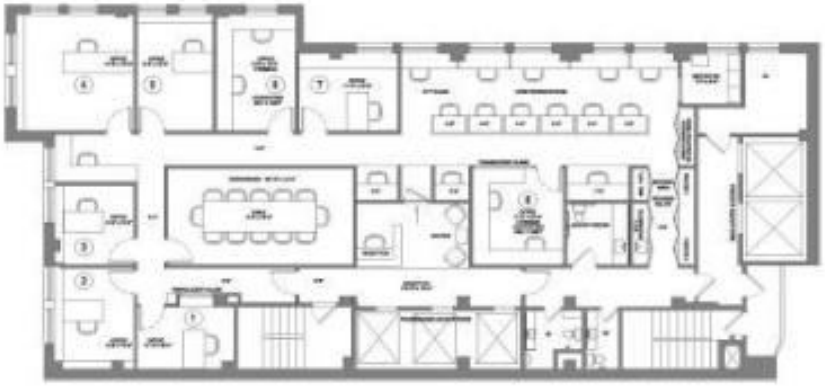


Figure 12.1 Traditional Cubical Form of Office
(***Source:*** google images)

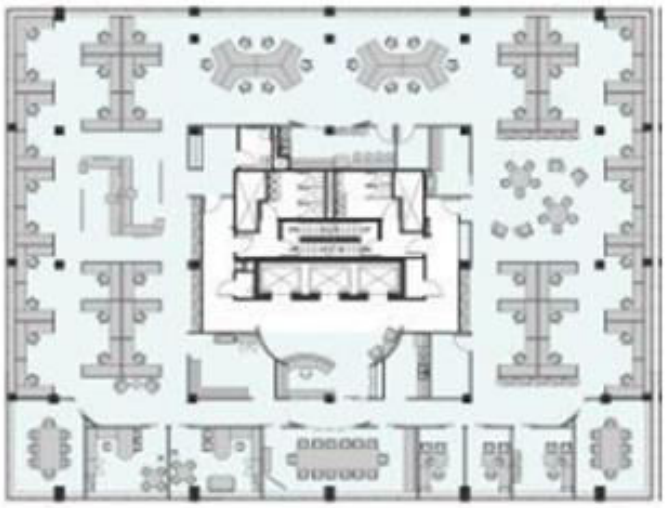


Figure 12.1 Modern Office Layout
(***Source:*** google images)

3.3. Spatial Planning Through Implication of Organizational Principles

Since an office is a system of interrelated activities and functions, while planning a space it is essential to focus on how spaces are related to each other. This organizes the form and order in the office. Organizational principles also lay a framework of specific communication patterns that are envisioned in the space [6].

3.4. Spatial Performance

Spatial Performance of an office is the contribution of physical space in organizational effectiveness. This can be achieved through:

- Optimized Space Planning.
- Reflection of organizational properties and attributes.
- Efficiency and comfort.

3.5. Spatial Planning Influencing Spatial Performance:

Factors explaining influence of spatial planning on spatial performance:

- Spatial Organization
- Based on Organizational principles.
- Based on typology of work spaces.
- Based on work modes.
- Based on hierarchical structure.
- Circulation and connectivity.
- Human Factors in a built environment

3.6. Spatial organization:

Spatial organization is discussed in images. Refer figures 12.3, 12.4, 12.5, 12.6 & 12.7)

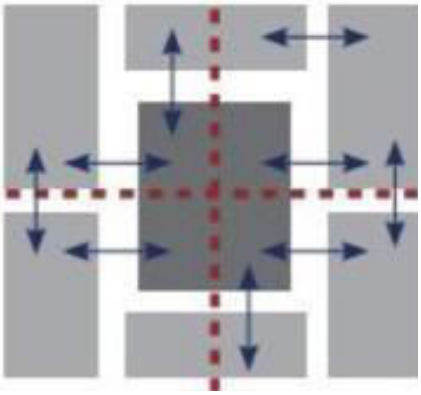


Figure 12.3 Centralized Organization
(***Source:*** google images)

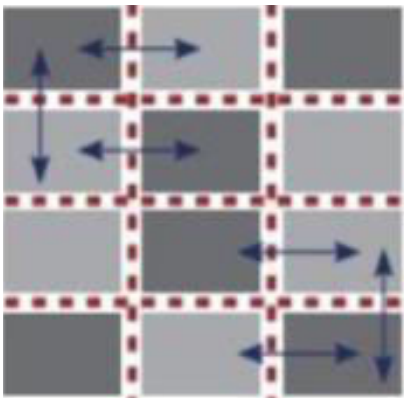


Figure 12.4 Grid Organization -Internal interactions & proximity.
(***Source:*** google images)

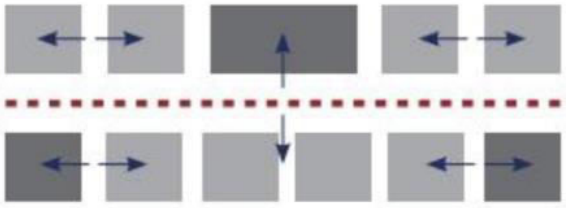


Figure 12.5 Linear Organization- Emphasizes individuality & reduce interaction.
(***Source:*** google images)

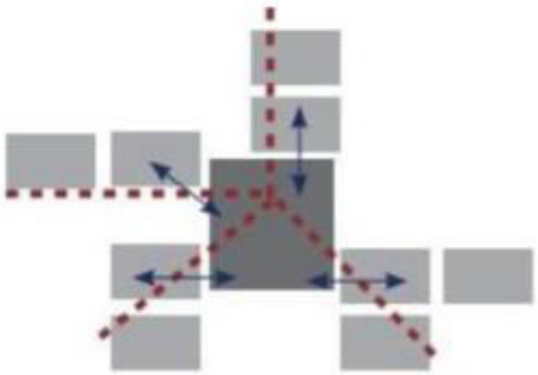


Figure 12.6 Radial Organization- Central Binding & Interactions.
(***Source:*** google images)

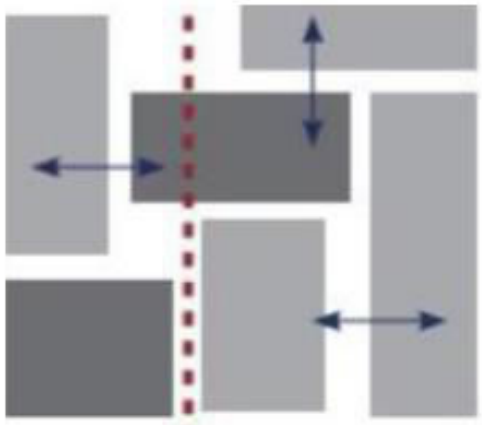


Figure 12.7 Clustered Organization- Increases Proximity.
(*Source:* google images**)**

3.7. Spatial Planning Through Typology of Work spaces:

This aspect of spatial planning through typology plays a vital role in office planning by identifying optimum correlations between working environment and work patterns and relating it to interaction and autonomy requested for working which is essential to facilitate the process of work. Refer figure 12.8.

1. **Hive:** This typology caters to the work that requires low autonomy and low interaction. Here there is full time occupancy and the office layout usually is open with minimal partitions and a pack of 4 to 6 workstations Clustered.
2. **Cell:** It caters to work that needs high autonomy and low interactions. Mainly the isolated knowledge work is categorized in this typology. The office layout for this typology is usually enclosed cellular spaces or workstations with high screening.

3. **Den:** This typology is for high interaction and high Autonomy. It is mostly for group work which requires a balance of different skills. The office layout incorporates various meeting rooms and collaborative spaces along with work areas.
4. **Club:** It demonstrates high interaction as well as high autonomy. The work pattern followed is generally for the organizations that need to work collaboratively as well as individually. The occupancy supports shared use of work settings. While the office layout is highly diverse based on a variety of tasks.

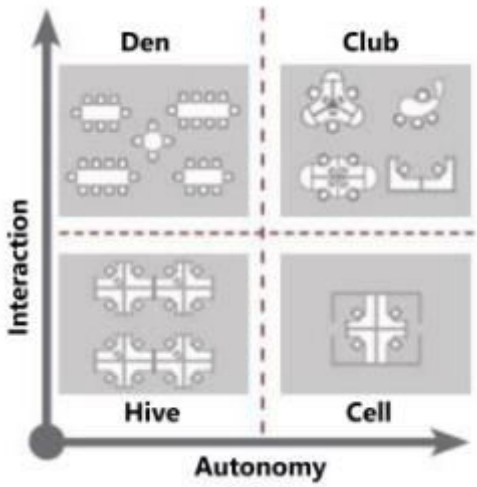


Figure 12.8 Relation between typology of work space and furniture layout.
(***Source:*** Planning, performance and productivity: An inquiry on spatial performance in office spaces, Patel C)

3.8. Spatial Planning Based on Work Modes:

1. **FOCUS WORK:** Concentration and complete attention to work on the ideas generated.
2. **COLLABORATION and LEARNING:** Discussions, knowledge sharing, brainstorming, problem solving, training and interacting.
3. **SOCIALIZING:** Created common goals, identity, network and trust increasing coordination and correlation. Refer figure 12.9.

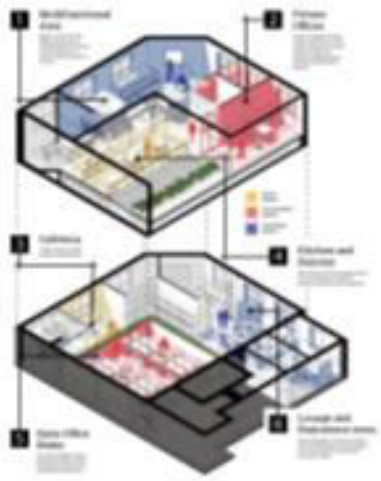


Figure12.9 Relation between spatial planning and work modes [3]

3.9. Hierarchical Structure

1. **Hierarchical Structure:** Employees are grouped based on function, geography and product. Dominant type of organization. Followed mainly in corporate, government organizations.
2. **Matrix Structure:** People with similar skills are grouped together for work assignments and reporting relationships are set up as a grid. Transferable hierarchy. Collaborative teamwork-based work pattern under vertical leadership structure.
3. **Flat Structure:** People with similar skills are grouped together for work assignments and reporting relationships are set up as a grid. Transferable hierarchy. Collaborative teamwork-based work pattern under vertical leadership structure.
4. **Network Structure:** More flexible and decentralized. Open communication. Open-ended environment with more collaborative interaction.
5. **Divisional Structure:** Independent operational workflow. Each organizational function has its own division which corresponds to either products or geographies. Balance of autonomy as well as interaction.
6. **Line Structure:** Chain of command flows from top to bottom and each department head has control over their departments. Independent decision-making power and self-contained department structure. An effective and stable organization structure.
7. **Team Based Structure:** Teams works towards a common goal while simultaneously working on their individual tasks. Flexible structure. Binding entity for coordination and performance is communication. Refer figure 12.10.

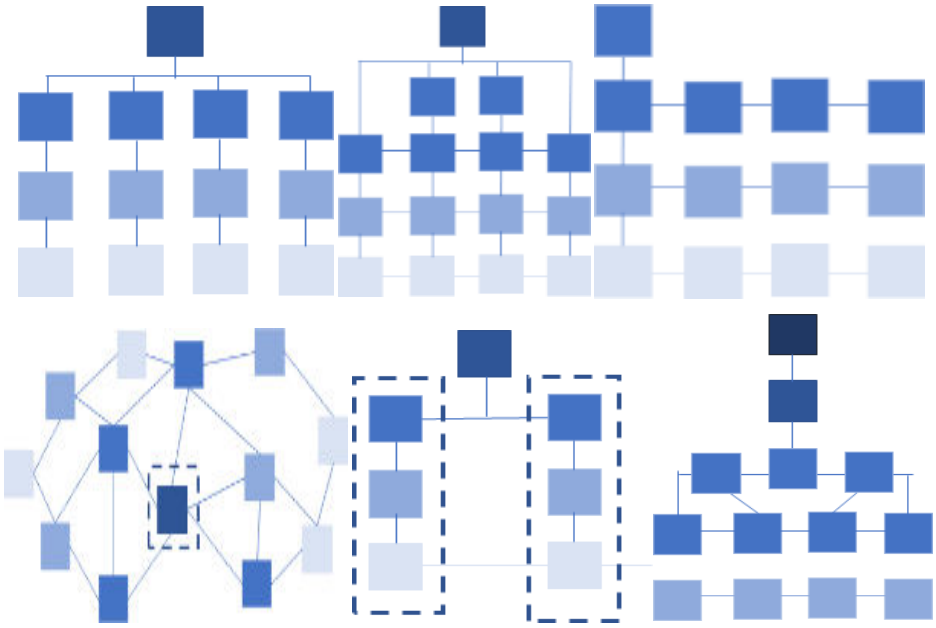


Figure 12.10 Hierarchical Structure
(***Source:*** Author)

a. Circulation establishes path-space relationships by connecting different spaces together.
b. The pattern of circulation binds the spaces creating opportunity to strategically plan activities which are needed to be encouraged in the space.
c. Plays a vital role in optimization of space.
d. Basic path configuration:

3.10. Human Factors in a Built Environment:

- Office design is challenging in terms of diversity of people that work in an environment. It varies from generation, gender and culture.
- There is diversity observed in work tasks, functions and hierarchical structure.
- Hence, office design needs to be addressed in a way that provides the right environment for the employees as well as visitors to ensure improvement in spatial performance.

3.11. Proxemic and Its Impact on Spatial Performance:

Proxemics is a study used to define relationships between humans within the space concerning proximity. It's the study of how people interact with each other as well as the space and relates to social, physical and psychological aspects of the space as well as the way spaces are planned.

This can be divided into different work modes:

- **Linear Arrangement (Focused Work Mode)**
  - Impact- reduces interaction and increases attention to individual work.
  - Inference- the furniture is arranged in a linear organization or a solo seating that interaction is discouraged.
- **Boxed Arrangement (Interactive Work Mode)**
  - Impact- It will facilitate a collaborative mode of working.
  - Interference- furniture arrangement in L-shape, Ushape, box-shape, circular as well as radial and spaces planned at right angles.
- **Adjacency (Mixed Workflow)**
  - Impact- different workstations are adjacent to each other to facilitate diverse working conditions.
  - Inference- Accessibility, usability, interactions and flow of communication is affected by the adjacency and proximity of one space to another.
- **Territorial Workflow**
  - Impact- mixed workflow of specific type at macro level. Area is divided visually rather than physically.
  - Inference- space is divided visually by separating the theme of spaces.
- **Crowding**
  - Impact- It is a situation resulting from a dense gathering of people.
  - Inference- proximity and concentration of heavy footfall areas highly create crowding like situations.
  - It can generate feelings of restlessness, insecurity and confinement.

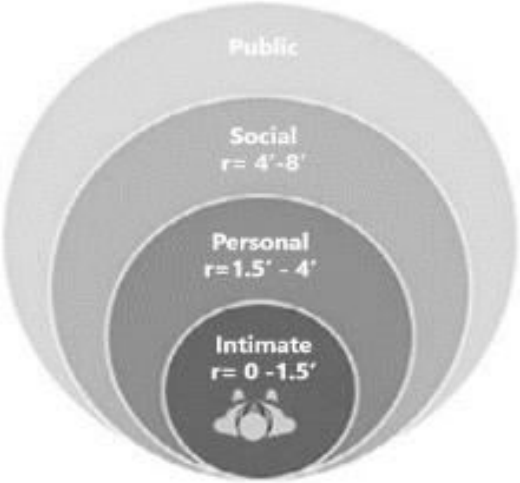


Figure 12.11 Human Proximity.
(***Source:*** Google Images)

3.12. Ergonomics

Ergonomics plays an important role in office in the placement of workstations and services. Important aspects of ergonomics include optimum placement of equipment and effectively aligning the workplace into the surrounding environment. Poor ergonomics leads to safety and health issues, as shown in figure 12.12.

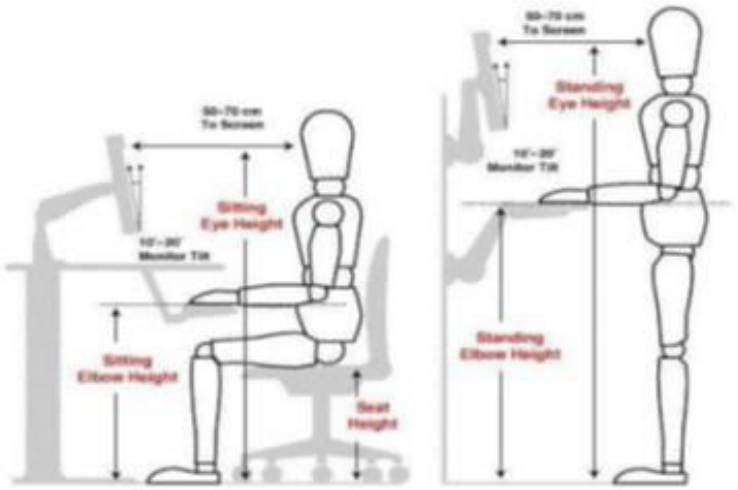


Figure 12.12 Ergonomics for Office Workstation
(***Source:*** Ergonomics, Purdue University

3.13. Orientation

It is another major factor that affects human factors. The orientation of spaces and furniture affect accessibility, interactions and while the movement of people passes through the back of workstations, it leads to a loss of privacy among employees which constantly bothers, inversely affecting employee performance.

3.14. Influence of Spatial Performance on Office Productivity:

Productivity is the increased organizational/office performance while upholding the quality standards with respect to the defined time frame. Office productivity is directly related to an employee's job performance.

Productivity depends on four primary aspects:

- Personal
- Social
- Organizational
- Environmental

Although it is difficult to get a precise relationship between the various individual factors and productivity, thorough study and well-thought spatial planning can achieve enhanced office productivity.

4. CASE STUDIES

4.1. Case Study 1: AICL Communications Office

Location: Andheri West, Mumbai

Area: 6000 sq.ft.

Office Type: Management Consultancy

Figure 12.13 Plan
(***Source:*** Planning, performance and productivity: An inquiry on spatial performance in office spaces, Patel C.)

4.2. Case study 2: BROWSERSTACK IT Company

Location: Mumbai

Area: 17300 sq.ft.

Office Type: IT, Software Development

Figure 12.14 Plan
(***Source:*** Planning, performance and productivity: An inquiry on spatial performance in office spaces, Patel C.)

Table 12.1 Parameter chart of the study

S.No	Parameter	Case Study-1	Case Study-2	Inference
1.	Organizational Structure	Matrix Hierarchical Structure	Flat Hierarchical Structure	Change in structure
2.	Hierarchy	Team-based organizational hierarchy. Reflected Through organization and qualities of spaces designed for the leadership.	The organization follows a flat hierarchy structure where employees are divided based on their departments.	Different office types have different organizational hierarchy hence require space layout reference to the structure.
3.	Space Planning	Space planning is done in such a way that open workstations and meeting rooms are placed in the major area zones	Space planning is done in such a way that collaborative meeting spaces, creative spaces are placed in the major area zones	Based on structure and work type and functions to be performed space layout is different for both the companies.
4.	Area Distribution	Being a consultancy firm, more space is allotted to private meeting room and individual workstation	Being a software development firm, more space is allotted to open lounge /group workstation and minimal meeting room area.	Area distribution is done on the basis of dominant and adjuvant functions that take place
5.	Work mode-based	As it is a consultancy	As it is a software	Work modes like

	area distribution	firm focus space i.e., workstation is placed in the centre and covers major part of the area ratio.	development company both collaboration space as well as focus space is necessary hence collaboration space is placed in the center and focus workstations are designed around it.	Focus Collaborate Learn Socialize Are once on the basis of which also areas are categories and planned
6.	Typology of work space	The typology of work space is formal interaction layout and individual focus workstations.	The typology Is concentrated majorly as interactive layout both formal and informal as work involves collaboration.	On the basis of interaction and autonomy the layout is opted to best suit the company requirements
7	Circulation in Space	Being a consultancy firm primary circulation runs longitudinally throughout the space with secondary circulation running in the periphery of the layout.	Being a software development company primary circulation is focused in the central collaboration space with secondary and tertiary circulation running around it.	Defined circulation based on level of privacy and control divided in 3 majors: Primary Secondary Tertiary
8.	Communication flow	Communication flow is maintained based on organizational hierarchy in this case it's restrictive, mostly 1 way type and more Controlled.	Communication flow is maintained based on organizational hierarchy in this case it's more interactive and to and fro type for collaborative work	Communication flow is determined based on hierarchy and interaction levels
9.	Control	Rigid Furniture layout is planned in the center to have control. Alternative and non-fixed furniture layout is planned around it	Non-fixed Furniture layout is planned in the centre to have controlled interaction and alternative working environment. And focus, fixed space is planned in the non-disturbed peripheral area	Levels of control on the space is determined on the bases of work performed in that space.
10.	Proximity (Adjacency)	Ancillary spaces for focus work is placed in the centre for direct	Ancillary spaces for collaborative work are centralized	How near or far 2 spaces should be, their direct

		connectivity with all other spaces around it and indirect connectivity to breakout zones. Here, private workstations are placed in the centre.	for direct connectivity with other spaces and breakout zones. here, semi – private space is planned in the central part of the layout as it ncourages and connects the major workflow	and indirect connectivity is determined on the working structure and hierarchy of the organization.
11.	Proximity (Territorialit y & crowding)	As it is a consultancy firm layout is more territorially divided and has a defined proximity in hierarchy	As it is a software development company is free flowing and planned as a single territory with flat type proximity in hierarchy.	Controlled crowding and few territorial spaces should also be taken into consideration in reference to the previous parameters.
12.	Interaction	Direct interaction is very focused and formal based on the communication flow layout	Direct interaction is slightly informal and collaborative type based on the communication flow layout	Distinct Direct and indirect interaction scopes in space planning should be taken in ccount for smooth and disciplined working. Interaction and communication flow are interdependent to one another
13.	Nodes of interaction	Spaces fostering Formal interaction is centrally placed in the layout to generate a focused and disciplined workflow.	Spaces fostering Informal interaction is Centrally placed in the layout to generate a collaborative workflow.	Major nodes of Interaction should be marked while planning to avoid chaos and Disturbance within the work space
14.	Physical qualities (Nature of Space)	Closed: open area ratio is 60:40 making the layout more rigid and controlled focusing on individual work flow	Closed: open area ratio is 20:80 making the layout best suited for collaborative and creative workflow type	Open to closed ratio, glazing. Ventilations are physical qualities that differ for different workspace, pleasant working environment should be one of the major aims while planning.
15.	Physical qualities	Exposed to outside views,	Well-lit by daylight coming from opposite	Adequate daylight should

	(Daylight in Space)	mostly artificial light used.	facades.	be welcomed while planning
16.	Physical qualities (Views)	No direct outside inside connection which lets employees focus.	Offer direct views which Produces distraction in terms of noise and external distraction.	Views according to work mode and typology should be proposed for maximum natural benefit.

5. RESULT

Through the comparative analysis of parameter chart of 2 case studies following inferences were identified:

Collaboration Integration of Collaborative Environment - Incorporation of more "We" spaces help in creating interaction opportunities while "I" spaces help in concentrated working. The ideal physical space is considered to be the one that creates a balanced space distribution of I and We spaces and lets people engage with uninterrupted focus work while encouraging socializing in abundance [7[.

Visual Co-Presence Connectivity- Face to face interactions are the key to efficient communication. Easy accessibility, primary circulation flow passing through the work area, open plan arrangement, clear visual connectivity and visual copresence result in a highly connected workplace directly infusing face to face interactions [8].

Accessibility Employee Engagement Collaboration- Planning of formal, informal and social meeting spaces in the nearest proximity to the work area such that they are easily accessible allows flexibility in the work environment and facilitates intra, inter-team collaboration and group cohesiveness leading to efficient interactions.

Employee Engagement- Alternate working environment and communal spaces are out most important to foster casual interactions and give flexibility and choice in work environments. They play a major role in building work relationships [9].

Job Autonomy Orientation- Circulation flow should be planned and oriented such that it loops all the interaction nodes as well as envelopes the work area while giving autonomy. Hot-desking and other mobile work environments are cost effective but reduce autonomy inversely affecting individual processing of work.

Orientation- Layout of furniture within a space represents the nature of the space, socio petal planning of spaces at macro level and socio fugal arrangement of workstations at micro level, help creating a balanced workspace since interaction is encouraged through planning while individual spaces get the required autonomy.

Reflection of Organizational Values- Ordering spaces based on work relationships directs efficient flow of communication. Making mistakes and improving on them increases scope of innovation. Hence when the company has an approach mindset, employees feel free to try out new things which might result in new ideas.

Spatial Density- Spatial density plays a vital role. When the space is highly concentrated, it leads to unrest, congestion and crowding.

6. CONCLUSION

The main focus of this research was exploring ways to increase productivity by improving the quality of the physical environment i.e., the workplace with the aim to reduce stress, encourage engagement, and help process better work output through design by taking parameters of spatial planning as lenses of study.

The key finding through this research paper is understanding and conceptualizing a design framework/layout as it correlates with factors of spatial organization, circulation and connectivity and physical quantities of space and parameters of proxemics, ergonomics, control and communication and orientation which reflects the work relationships, organizational structure, environmental factors impacting on employee's performance resulting in the overall office productivity.

The future scope of this research can be focused on defining further constraints and identifying parameters (like pandemic ready) for generating layouts through generative design by merging humans, space and technology. Also, future study on conceptualizing similar frameworks by identifying parameters could be generated for other public spaces to eliminate intuitive linear design decisions and approaching more of an organic and user experience design layout.

REFERENCES

1. Ching, F.D.K. (2014). "Architecture- Form, Space, & Order." Cp- 4 pp.183-185 Wiley. Available: https:// www.google.co.in/ books/edition/ Architecture/ yBzVBAAA QBAJ?hl=en&gbpv=1&printsec=fr ontcover
2. Patel, C. (2020). "Planning, performance and productivity: An inquiry on spatial performance in office spaces". Issuu Inc. 1-15.
3. Andrade, H. (2016). "Performative Space Interior Design. [Online]". Architecture Research. 1-10. Available from: https://www.behance.net/gallery/44834059/CRC-Office-Performative-Space-Interior-Design
4. Baher Ismail Farahat, Helga Omar Alaeddine (2020). "Towards Improving the Quality of Workspaces for a Better Human Performance in Lebanon". International Conference on Architecture and Civil Engineering. 85-102.
5. Harsha Latha, Shantharam Patil & Pradeep G. Kini (2022). "Influence of architectural space layout and building perimeter on the energy performance of buildings: A systematic literature review". International Journal of Energy and Environmental Engineering. 1-44.
6. Mohammad A Hassanain (2010) "Analysis of factors influencing office workplace planning and design in corporate facilities". Journal of Building Appraisal. 183–197.
7. Arjun Kaicker, Uli Blum, Philipp Siedler &Lorena Espaillat "Enhancing Workplace Design through Advanced Floor Plate Analytics". Technology|Architecture + Design.
8. Zeynab Yousefizadeh, Seyed Hadi Ghoddusifar (2016) "Assessing the role of architectural space in enhancing human force productivity". International Journal of Organizational Leadership 5.199-207.
9. Rasha Mahmoud Ali El-Zeiny (2012). "The Interior Design of Workplace and its Impact on Employees' Performance: A Case Study of the Private Sector Corporations in Egypt". Procedia - Social and Behavioral Sciences 35 746 – 756.

ABOUT THE EDITORS

Ar. Preeti Nair

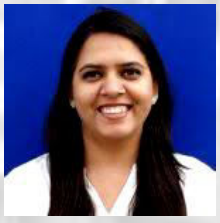
She is presently working as Associate professor in Department of Architecture, Delhi Technical Campus, Greater Noida. She has graduated from Giani Zail Singh College of Engineering and Technology, Bathinda under Punjab Technical University in 2008. She has done her Masters in M.Ekistics from Jamia Millia Islamic, New Delhi in 2012. She has an experience in the industry for more than 5 years with wide range of projects varying in institutional and residential projects. She has been associated with Amity University, Galgotias University since 2012.Her research interest is in architectural design, urban planning and Town Planning. She is currently pursuing PhD focusing on the settlement morphology of rural settlements. She has been speakers in many National and International conferences. She has also authored 5 papers out of which three papers are in Scopus and 1 in Web of Science Journal.

Prof. Pranay Tanwar

He is currently working as Professor and donning the mantle of Dean Academics at Delhi Technical Campus, Greater Noida, a premier institute affiliated to GGSIP University, New Delhi. She has almost twenty-four years of academic experience in teaching and research. Prof Tanwar is forward thinking and experienced academician, possessing drive, ambition and ability to make consequential contribution in the field of educational administration. Prof Tanwar research interest includes optimization, operation research, quantitative research, green design etc. She has published and presented various articles in Journals and Conferences. Dr Pranay has been successfully conceptualizing and operationalizing various academic and cultural events.

Dr. Mohd Atif Wahid

He is currently working as an Associate Professor in the Department of Mechanical and Automation Engineering at Delhi Technical Campus (GGSIPU), Greater Noida, India. He is also the in charge of the Research Cell at the institute level. He received his PhD and Masters in Mechanical Engineering in the year 2018 and 2013, respectively from Jamia Millia Islamia (A Central University), New Delhi, India. His major research interest includes, material processing and characterization, optimization of design using evolutionary approaches, sustainable engineering, green manufacturing etc. He has approx 10 years of experience including industry, teaching and research. He is a reviewer of reputed Journals such as International Journal of Advanced Manufacturing Technology (Springer), Multidiscipline Modeling in Materials and Structures (Emerald), Kovove MaterialyMetallic Materials, Indian Journal of Engineering & Materials Sciences (NISCAIR), Journal of Engineering Manufacture (SAGE), etc. He has published and presented above 50 articles in SCI/ Scopus indexed/UGC Journals, International and National Conferences. Dr Wahid has been an active member in organizing various international/national conferences, workshops, seminars, webinars etc. He is also the Editor of various Journals and Conferences.



Ar. Swati Punyal

She is presently working as Assistant Professor in Department of Architecture, Delhi Technical Campus, Greater Noida. She has graduated from Sushant School of Art and Architecture, Haryana under GGSIPU in 2014. She has done her Masters in Urban Design from School of Planning and Architecture, Bhopal in 2018. She has an experience in the academics for more than 5 years. Her research interest is in Architectural Design, Urban Design and Environmental Planning. She is currently pursuing PhD focusing on Disaster Resilience planning in Hilly regions.

ABOUT THE BOOK

This book compiles the current research studies in the field of architecture which explore new technologies and urban practices. The book topics includes building design and construction, design management and design coordination, facilities management and various other fields that are related to architectural field. The aim of the book is to build strong communication link between the research communities. Innovative and multi-disciplinary studies promoting an integrated approach to planning, design, construction and operation of buildings are especially encouraged. The primary audience of this book will be academics and professionals from the fields of architecture, landscape design, urban design, urban planning, civil engineering, computer sciences, and environmental studies. The book will aid them in their contributions towards sustainable development in built environment.

EMPYREAL PUBLISHING HOUSE

ISBN 978-93-93810-64-9

India | UAE | Nigeria | Uzbekistan | Montenegro | Iraq | Egypt | Thailand | Uganda | Philippines | Indonesia

www.empyrealpublishinghouse.com