TEAM SHUNYA
Building a sustainable future

INDIAN INSTITUTE OF TECHNOLOGY BOMBAY

Architecture

U.S. DEPARTMENT OF ENERGY
SOLAR DECATHLON

Jury Documentation

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Introduction

Mumbai, the financial capital of India, is grappling with an affordable housing crisis due to rapid population growth and rising real estate prices. According to the 2011 census, the population of Mumbai was 12.5 million, estimated to have increased to around 20 million in 2021. This population growth has put immense pressure on the city's infrastructure and resources, including housing. According to the Report on The State of Affordable Housing in Mumbai,

- 41.9% people in Mumbai live in slums
- 57% households live in one room dwellings
- In nine out of 24 wards, more than 50% of population lives in slums

The affordable housing crisis in Mumbai has hit the low and middle-income groups the hardest. The high housing cost has pushed many people to live in slums and informal settlements, where they face poor living conditions and a lack of basic amenities such as water, sanitation, and electricity which is a serious concern. The lack of affordable housing has led to overcrowding, poor living conditions, and other social problems.

Climate in Mumbai

Mumbai is located on the western coast of India and has a tropical climate. The city experiences three distinct seasons:

- Hot and humid summer from March to May
- Monsoon season from June to September
- Cool and dry winter from November to February

During the summer, temperatures can rise above 40°C (104°F), and the humidity can make it feel even hotter. The monsoon season brings heavy rainfall, with July being the wettest month. The winter months have temperatures ranging from 15°C to 30°C (59°F to 86°F).

Mumbai is also experiencing the impacts of climate change. The average temperature in Mumbai has been increasing steadily over the past few decades, with a rise of about 0.5°C (0.9°F) per decade, leading to health issues, increased energy demands, and water scarcity.

Mumbai is also experiencing changes in its precipitation patterns. While the monsoon season still brings heavy rainfall, the frequency and intensity of extreme rainfall events have been increasing, leading to flooding in many parts of the city. On the other hand, the winter months are becoming drier, which can impact agriculture and water availability.

Navi Mumbai as a future of housing in Mumbai

Navi Mumbai is a rapidly developing economic center that has attracted people from India's Tier 2 and Tier 3 cities looking for job opportunities. This has created pressure on Mumbai's resources, from water to housing to transportation, making sustainable living crucial. Navi Mumbai has been carefully planned as a solution to this issue, with an abundance of job opportunities attracting many individuals to the region.

Project Client

A family of four, consisting of a married couple and two children, who have recently moved to Navi Mumbai in search of better job opportunities and a higher standard of living, are interested in building a home that operates on net-zero energy principles.

For this family, building a net-zero energy home is an opportunity to reduce their carbon footprint and save money on energy bills in the long run.

Architectural Design

Phenomenology

The influx of job-seekers to Mumbai comprises people from India's Tier 2 and Tier 3 cities. The diversity in Navi Mumbai enriches the city and shapes the personalities of its inhabitants. But the generic urban spaces and apartment lifestyles can be disorienting and alienating for many. Preserving traditions can ensure the city's sustainability for generations. One way to achieve the above goal is to design homes with the conceptual framework of Phenomenology. Using the Phenomenological approach to design homes can create spaces that meet the needs and perceptions of the inhabitants and provide a more comfortable living experience. The approach considers the emotional and sensory aspects of the living experience, including color, texture,

and scent, and designing living spaces that deepen the connection to the surroundings. It also considers the social and cultural context of the house by designing spaces that promote social interactions and the expression of cultural traditions. It is all about creating an abstract experience that transcends the tangible.

Spaces are concretization of values

The design of architectural spaces is a concrete expression of underlying values and priorities, which can shape how residents interact with each other and the environment. These value systems contribute to the social, cultural, and environmental context of the spaces within the residence, and can impact the division of private and public spaces, as well as gendered spaces. While value systems change over time, physical spaces are often the last to adopt and concretize these changes. However, at times, the physical spaces can also be in the foreground of social and value changes.

In Maharashtrian vernacular houses, a Wada (Shown in **Error! Reference source not found.**) typically refers to a house with a central courtyard, surrounded by smaller rooms and living spaces.

The design of the house draws inspiration from the vernacular house typology of the region called Wada, to transform our 'house' into a 'home'. The spatial hierarchy and relation of spaces in the Wada has guided the design of the house, with spaces like the living room reimagined as baithak and the dining area as angan. While the Wada design holds some outdated value commitments, such as gendered division of spaces, the open kitchen design has been adopted to address this.
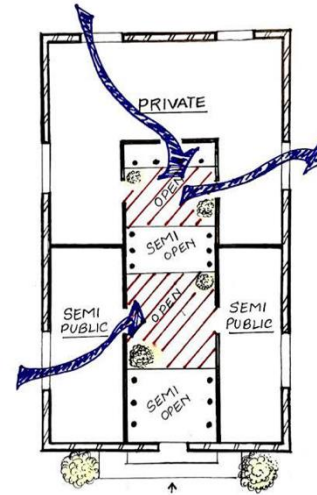

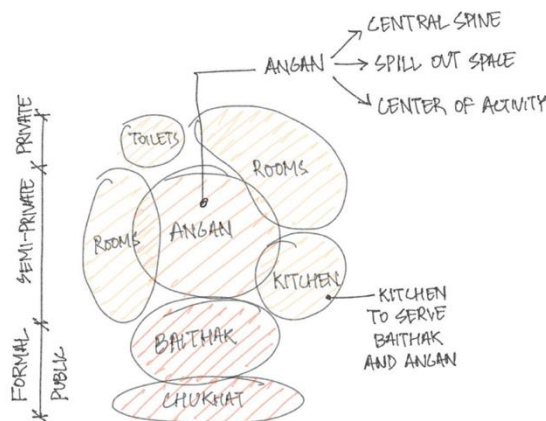*Figure 1 - Typical Maharashtrian Wada Plan*

Figure 2 - Conceptual Layout of Wada

Zoning of Spaces

Zoning a residence involves dividing it into public, private, and semi-private zones, which provides several benefits, such as improving privacy, organization, comfort, and aesthetics. It also allows for designing the home according to climatic requirements to create a comfortable living environment. Special attention is given to different qualities of different functional spaces in residence. For instance:

- Most used spaces such as dining and baithak are in the northern direction and get diffused zenithal sunlight from the north
- In India, there is a gendered division of spaces where women occupy the kitchen and men occupy the sit-outs, leading to an unfair workload on women. To address this issue, contemporary designs are incorporating open kitchens to reduce the gendered division of spaces
- Bedrooms are placed in the west direction (predominant wind direction) to harness the wind for passive cooling.
- In traditional Indian homes, the Aangan or courtyard is a vital part of daily life and is used for socializing with family, friends, and neighbors. It is also a safe space for children to play. In modern homes, the dining and living areas have become the contemporary Aangan, serving as a multi-functional and flexible space where the kitchen, religious and cultural activities spill over, allowing families to come together.
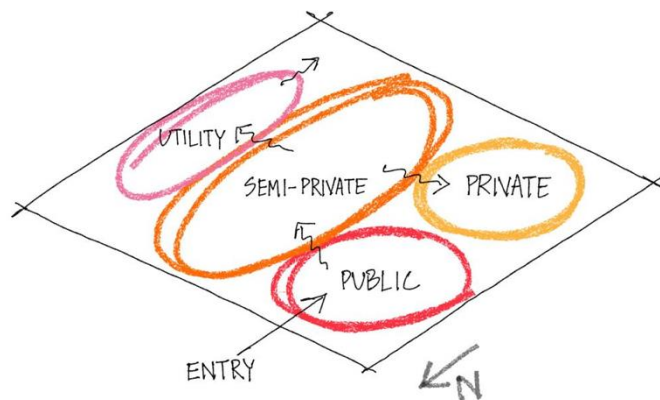

Figure 3 - Zoning of difference spaces in the house

Sense of Intimacy

Designing a residence with a sense of intimacy involves creating spaces that foster warmth, comfort, and personal connection. This is achieved through creating cozy and inviting small spaces, using warm colors, soft textures, and comfortable furnishings, and designing spaces that facilitate social interactions. Incorporating natural light, fresh air, and greenery also helps to create an intimate atmosphere. The scale of the areas reduces as the sense of intimacy increases, and dark-colored tiles are used in private spaces like bedrooms. Large windows,

skylights, and indoor plants create a connection with the outdoors and provide a sense of calm and tranquility.

Connectedness

Visual connectivity in residential design involves connecting spaces within a home to create a sense of openness and harmony. This can be achieved through open-plan layouts, removing walls between rooms, maximizing natural light, and creating an indoor-outdoor connection. The use of Jali can provide a visual connection while maintaining privacy. A consistent design language throughout the home is also important, using similar materials, colors, and textures to create a cohesive and unified design.
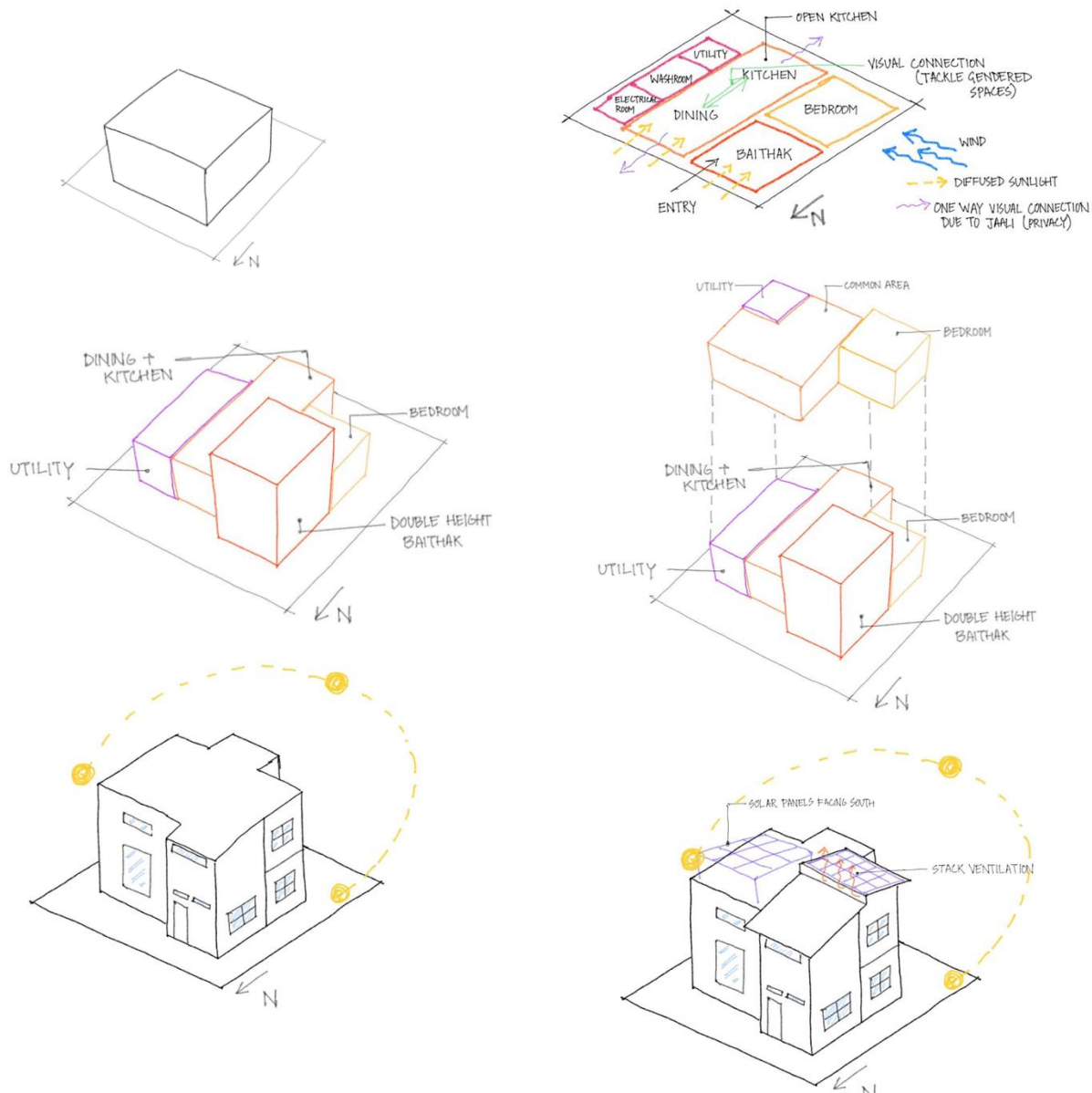

Figure 4 - Architectural Massing

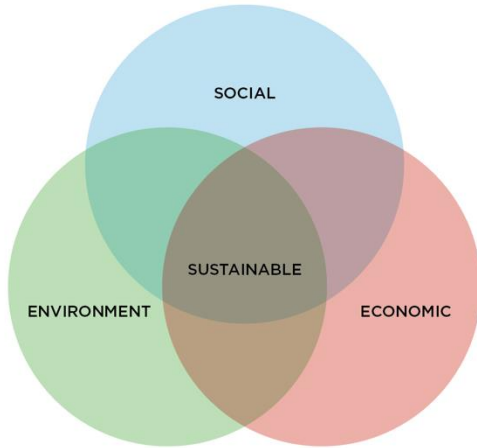# Blending Phenomenology with Sustainability

Figure 5 - Pillars of Sustainability

The project integrates phenomenology and sustainability to create a sustainable and pleasant living experience. The focus is on the sensory and emotional experience of the users, while considering all aspects of sustainability including social, economic and environmental factors.

Social Sustainability

The concept of social sustainability involves promoting equity, inclusivity, and justice in society by meeting basic human needs, protecting cultural heritage, and encouraging community engagement. The house's design supports social sustainability by ensuring the well-being of occupants, fostering community engagement, and adapting to changing needs. The communal spaces such as extended living area, dining area or play area, office space, etc. accommodate large gatherings, are accessible to all ages and abilities. A front porch or a backyard encourage interaction with neighbors. Locally sourced materials and labor are used to support the local economy and contribute to the social sustainability of the neighborhood.

Economic Sustainability

The concept of economic sustainability involves balancing economic growth with environmental protection and social well-being. The house in question considers economic sustainability by reducing build, maintenance, and operational costs. The house is designed to be energy-efficient and cost-effective by incorporating materials such as insulation, windows, and appliances. Passive design strategies, such as north-facing windows and small openings in the southern facade, help reduce solar gain and lower the need for heating systems. The house size is optimized for the needs of its inhabitants, especially the bedrooms, and allows for future expansion.

Environmental Sustainability

The house is designed with environmental sustainability in mind by reducing energy consumption and carbon emissions. For example, the house is designed to be environmentally sustainable with features that reduce energy consumption and carbon emissions. Natural light is used to minimize solar heat gain, and sustainable materials and energy-efficient systems are used to lower the building's environmental impact as explained in the implementation section. The project also includes water-efficient systems that can minimize water consumption and environmental impact.

The three pillars of sustainability, social, economic, and environmental, are interconnected and cannot be considered separately

Material Selection

The material selection process is critical for sustainable housing, and it's essential to consider the environmental impact throughout their entire lifecycle, from extraction to disposal.

- **Steel:** Steel is a highly sustainable material which is used due to its recyclability, durability, and high versatility.
- **Ecoboard**: Ecoboard is an Agro-waste based board that reduce waste, is recyclable and has less embodied energy.
- **Refurbished furniture:** Refurbishing furniture can reduce waste, conserve resources, and increase energy efficiency. It is a great way to create a unique, customizable, and personalized home while lowering environmental impact. It reduces the need for new materials and resources to produce new furniture.
- **High-performance glazing:** Double-glazed windows are installed strategically to reduce need for active cooling/heating by avoiding heat loss and solar heat gain.

Energy Conservation and Energy production

The conservation and production of energy are crucial aspects of sustainable housing design, as they help reduce the carbon footprint of a building and promote energy efficiency. Passive design strategies, building envelope design, and energy-efficient systems are some of the approaches used to achieve this. Passive design involves maximizing natural light and ventilation, while building envelope design focuses on creating a well-insulated and airtight envelope. High-performance windows and doors with low-e coatings can also significantly reduce heat transfer. Energy-efficient systems such as energy-efficient appliances, lighting fixtures, and plumbing (MEP) systems help reduce energy consumption in a building.

Implementation

Ventilation

Ventilation is critical to sustainable housing design as it affects indoor air quality, energy consumption, and overall comfort. A passive ventilation system uses natural airflow to provide fresh air and regulate the temperature in the building without relying on mechanical systems.

Some passive ventilation systems used in the house design are:

- **Cross-ventilation**: The bedroom windows are placed on the predominant wind direction's western facade. This helps in reducing the cooling loads and provides good air quality.
- **Stack ventilation** involves creating a pressure differential between the top and bottom of the building to allow hot air to rise and escape through vents at the top while drawing in cool air from below. This has been used in the design of the baithak.
- **Natural ventilation with fans**: Natural ventilation can be enhanced by using fans to increase airflow. Fans can be powered by solar to minimize energy consumption.

Natural Lighting

The house design places a significant emphasis on natural lighting, which has various benefits such as reducing energy consumption and improving indoor environmental quality. The design takes advantage of proper house orientation, strategic window placement, and high-performance glazing and shading systems to maximize natural light while minimizing heat gain. The North facade of the house has the majority of large windows to receive diffused sunlight. Open floor plans with fewer walls and partitions allow natural light to penetrate deeper into the building, improving the occupants' connection to the outdoors and overall well-being.

Wall Assembly for Thermal Comfort

Glass wool and Eco-boards are materials that can help promote passive cooling strategies in sustainable housing design by keeping the interior of the building cooler without relying on mechanical cooling systems.

Glass wool is made from recycled glass spun into thin fibers, used as insulation to reduce heat transfer between the interior and exterior of a building.
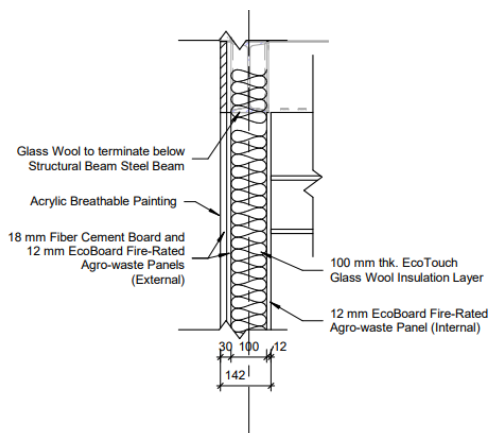

Figure 6 - Schematic of Wall Assembly

Eco-boards are structural insulated panels made from recycled wood waste, providing excellent thermal insulation properties and an alternative to traditional wood framing. When combined with glass wool, they create a hybrid system that offers both insulation and structural support, suitable for use in wall assemblies.

Supplementary Bamboo Structures

Bamboo is a fast-growing, renewable resource used for shading purposes. It is a highly sustainable material with rapid growth, renewability, and the ability to sequester carbon. It adds a unique and natural aesthetic to the building. In addition, it is highly durable, reducing the need for mechanical heating and cooling systems and is cost-effective.

Jali

Jaali, also known as latticework or perforated screens, is an Indian traditional architectural element used in Indian housing design for centuries. Jaali is a sustainable design element used to provide passive cooling, daylighting, privacy, aesthetics, and cost-effectiveness.

Water Conservation

Navi Mumbai is located in a region that receives heavy rainfall during the monsoon. Therefore, water harvesting and greywater recycling can be sustainable due to the and high population density and city's water scarcity.

Rainwater harvesting is a great way to conserve water and reduce the strain on the municipal water supply in cities like Navi Mumbai. It can help reduce the load on the city's water supply system, often stressed during peak demand periods.

Greywater recycling can save water bills by providing a reliable water source for non-potable purposes, such as flushing toilets and irrigating gardens. It also reduces the burden on the city's wastewater treatment infrastructure and improves the quality of water in the city's water bodies.
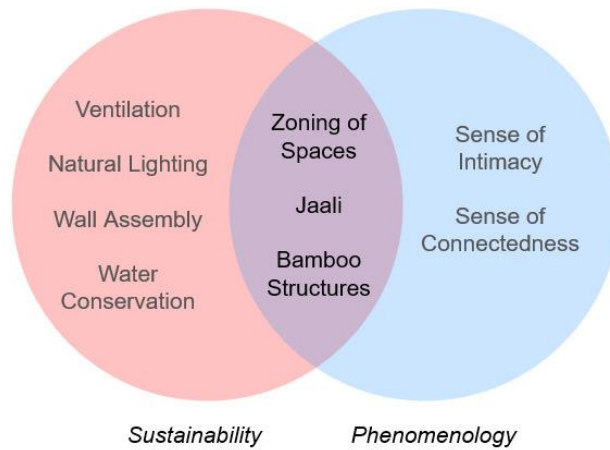
Summary

Figure 7 - Conceptual Framework

The house is an amalgamation of new technology and vernacular knowledge. It is a perfect example of a contemporary vernacular house with the latest technology being incorporated with the conceptual framework of phenomenology, which makes the 'house' a 'home'.

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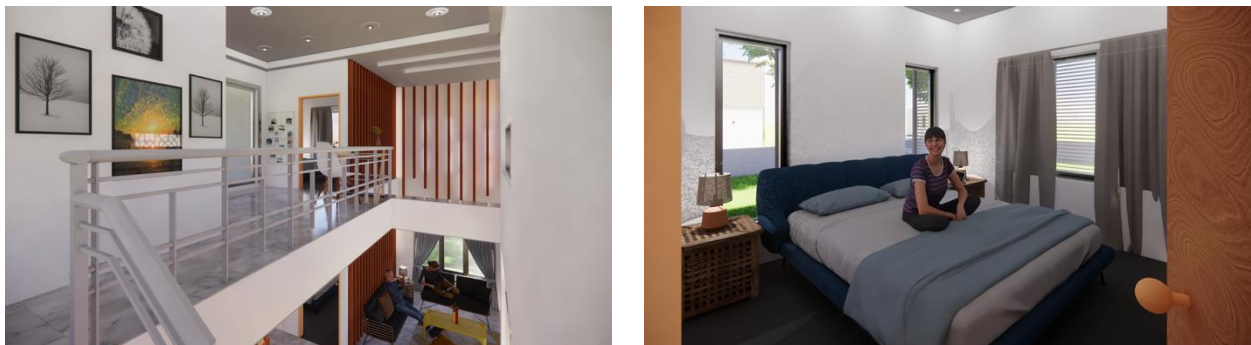
Photos Highlighting Design Features

Figure 8 - On left: Double-Heighted Living Room, on right: Bedroom

Figure 9 - Common Space in First Floor

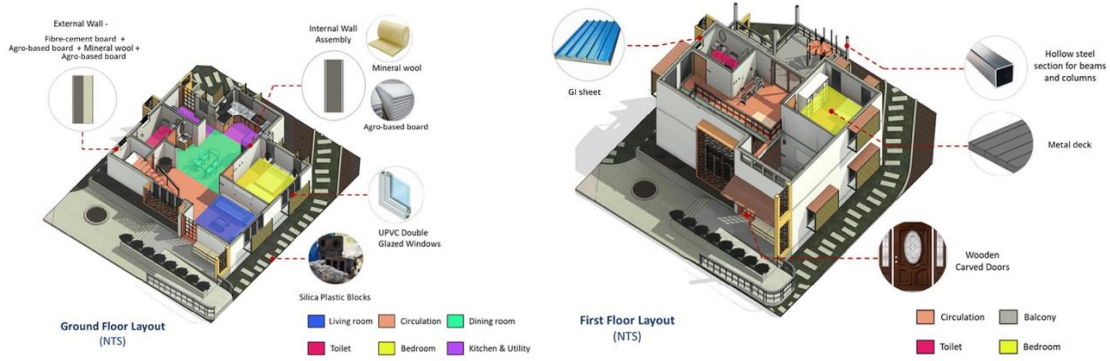*Figure 10 - Large windows on the Northern side*

Figure 11 - Jali used in Windows

Figure 12 - Materials used for the Envelope